PHOTOVOLTAIC MONITORING DATABASE FINAL REPORT NOVEMBER 1, 1986 TO JUNE 30, 1987

RENEWABLE ENERGY BRANCH

PREPARED FOR:

Renewable Energy Branch
Energy, Mines and Resources Canada
Ottawa, Canada
DSS File Number 23216-6-6113/01-SZ
July 1987

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ACKNOWLEDGEMENTS

T E S Limited would like to acknowledge the assistance of the staff of Environment Canada, Water Resources Branch.

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PREFACE

In 1986, T E S Limited proposed and was chosen to initiate and conduct a nine month monitoring contract for the EMR Solar Energy Development Program. The objectives of the monitoring program were to provide continuous collection, analysis and distribution of photovoltaic operating data as well as diagnosis of failures or operating problems of photovoltaic systems.

The purpose of this report is to present a summary of all work completed during the contract and to present conclusions on overall system performance and recommendations for future site monitoring systems.

ABSTRACT

T E S Limited has developed a nine month monitoring program for the EMR Solar Energy Development Program. The objectives of the program were to provide continuous data collection from Environment Canada Data Collection Platforms (DCP), to perform remote diagnosis of photovoltaic system problems and failures, to provide IBM-PC compatible data for independent study, and to produce monthly reports summarizing the site performance.

The monitoring program involved monthly data collection from two Environment Canada Data Collection Platforms, Coppermine River NWT and Lake Diefenbaker Saskatchewan. The data were collected from sensors monitoring system electrical parameters and included site temperatures and solar insolation data.

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EXECUTIVE SUMMARY

T E S Limited submitted a proposal which was accepted by EMR to establish a monitoring database of photovoltaic installations. Two Environment Canada DCP's, Coppermine River NWT and Lake Diefenbaker Saskatchewan, were selected as pilot sites to initiate and test the monitoring program.

It was initially proposed that the data be collected and transmitted via modem to T E S facilities in Ottawa. Final installation had data being transmitted every 3 hours from the collection site via satellite to Washington D.C. where it was then transferred daily to Environment Canada in Hull, Quebec. On a weekly basis, data from Hull was transferred via modem to T E S facilities for processing and analysis. Progress reports were then produced monthly for general distribution to EMR, Environment Canada and the Ontario Research Foundation.

The Coppermine River Site came on stream in November, 1986 providing eight months of data. Lake Diefenbaker started transmitting data regularly in late February, 1987 providing four months of data.

Both sites' data have followed the expected trends or curves which are based on historical averages.

1.0 INTRODUCTION

The Department of Energy, Mines and Resources (EMR) has initiated the Solar Energy Development Program to solicit investigative proposals with respect to Solar Energy T E S Limited proposed to establish a photovoltaic monitoring database. This proposal was accepted by EMR and to date has resulted in a nine month monitoring program.

Previously, the selection of photovoltaic components has been based on the user's experience and manufacturer's data. Optimization of systems with respect to cost, size, weight or performance was not possible beyond the realm of educated guesses. The establishment of the database will provide the tool with which the user can optimize his system.

2.0 OBJECTIVES

The objective of this program was to establish a photovoltaic monitoring database for evaluational purposes. The program provided EMR with:

1) continuous collection of operating data for two remote PV systems.

2) remote diagnosis of PV component or system problems and/or failures.

3) IBM-PC compatible data for independent study.

4) monthly reports summarizing and plotting operating data and site performance.

5) site operating history logs for reliability and performance evaluation.

3.0 METHOD

Photovoltaic system performance data are collected at the site on an hourly basis, are interfaced by the T E S Limited voltage-frequency converter to an Environment Canada Data Collection Platform and transmitted every three hours by satellite to Washington D.C. The data are collected and stored in Washington for one day (24 hour period) before being transferred via modem to Environment Canada Offices in Hull, Quebec. All data will be stored at Environment Canada facilities for one year. Every week, data are transferred from Environment Canada to T E S Limited, again by modem. At T E S Limited, the data are processed into engineering units, tabulated, graphed and monthly reports are generated for distribution. It is during the generation of the monthly report that the data are examined for conformance to predicted normals (AES) or expected operation and diagnosis of problems or failures is performed. These findings are incorporated in the monthly report.

3.1 Equipment

The two sites selected for this development program are Coppermine River, NWT and Lake Diefenbaker, Saskatchewan. The sites, whose locations are shown in Figure 2, are owned and operated by Environment Canada to report hydrometric data, via satellite, to their offices in Hull. Coppermine River, NWT is located at 67^{o}N, 115^{o}W. Lake Diefenbaker, Saskatchewan is located at 51^{o}N, 107^{o}W.

Each site consists of a photovoltaic array, a voltage regulator, 12 volt batteries, data collection equipment and a satellite transmitter. Added to each site was a set of sensors and voltage-to-frequency (V/F) signal conditioning circuitry. The data collection equipment records the sensor readings every hour for transmission, via Washington D.C., to Hull, Quebec. Readings for all "COUNT" type channels will report a true average value integrated over the complete hour period. Readings for all "ANALOGUE" type channels will report an instantaneous value read at the end of the hour. The six channel low power V/F circuit was designed and built at T E S Limited where the entire panel and sensor array was

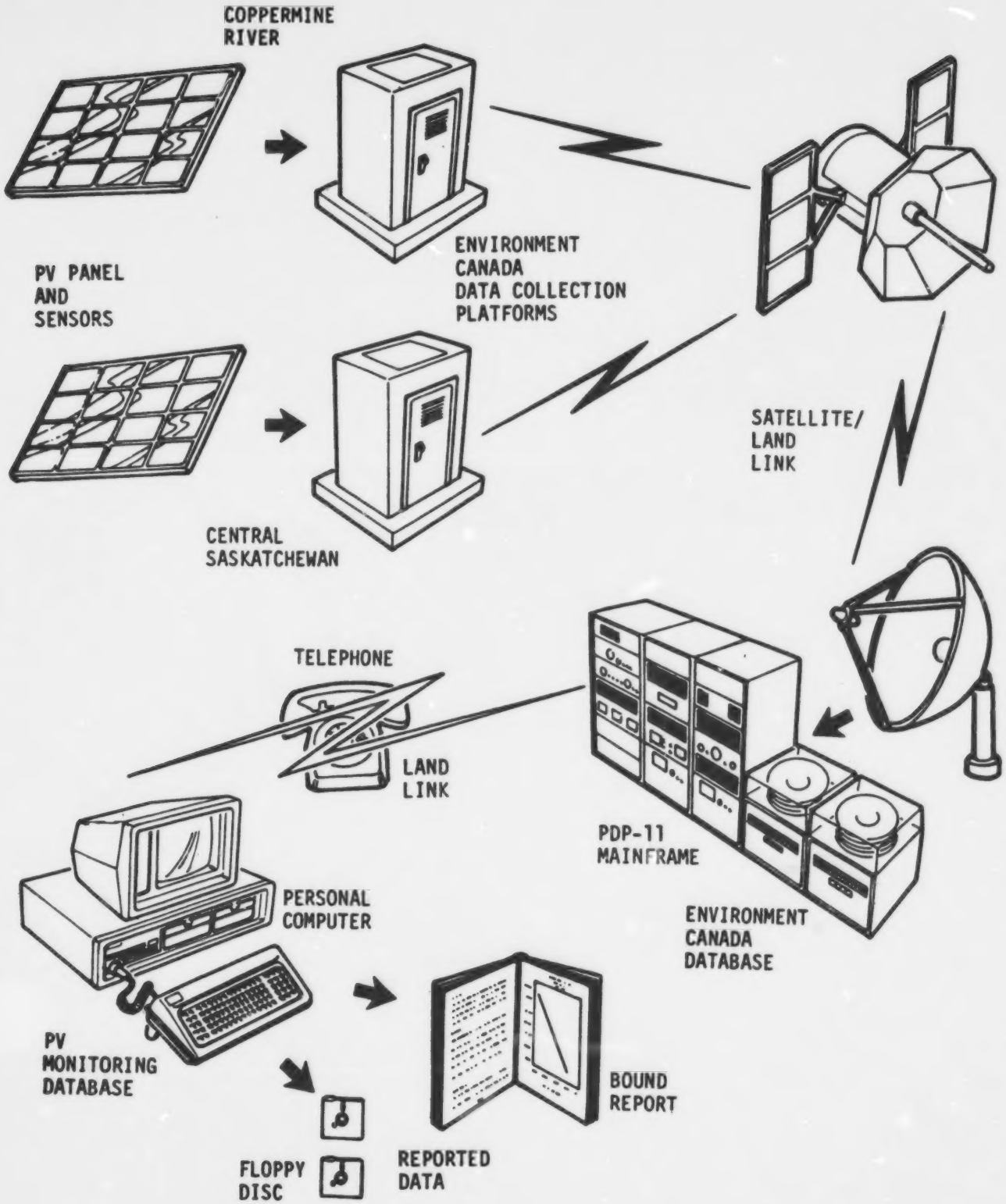


FIGURE 1

Photovoltaic Monitoring Network

Figure 2
Site Locations

Table 1

Reported Site Parameters

	DATA TYPE
Horizontal Insolation (kJ/m2)	COUNT
Vertical Insolation (plane of PV array) (kJ/m2)	COUNT
Panel Voltage (V)	COUNT
Battery Voltage (V)	ANALOGUE
Charge Current (mA)	COUNT
Discharge Current (mA)	COUNT
Ambient Temperature (^{o}C)	ANALOGUE
Panel Temperature (^{o}C)	ANALOGUE
DCP Internal Temperature (^{o}C)	ANALOGUE

assembled and tested before shipment.

The sites are equipped with similar equipment with the exception of the voltage regulators. Coppermine River uses a zener diode and a blocking diode while Lake Diefenbaker uses a switching shunt regulator. Both sites use two, six volt, 212 amp-hour Varta batteries connected in series to power the site load. These batteries are charged by a vertically mounted ten watt Solarex photovoltaic panel. The panel is mounted vertically to lessen the amount of dust and dirt which collects on the panel. The sites are instrumented with a servo manometer and Memomark III transmitter. The batteries provide power to the manometer, to the Hydromet DCP, the satellite transmitter, and to the T E S Limited voltage-to-frequency converter.

3.1.1 Coppermine River

The voltage regulator for this site consists of a blocking diode in the negative arm of the charging circuit and a 14.5 volt zener diode across the PV panel output. The zener diode prevents the PV panel voltage from rising above 14.5 volts and overcharging the battery The battery charges whenever the battery voltage is less than the PV panel voltage plus the blocking diode voltage. The battery is considered at full charge when the battery voltage is equal to the zener voltage, at this point there is no charge current and all excess PV panel current is shunted to the low voltage terminal.

3.1.2 Lake Diefenbaker

The voltage regulator for this site is a Solarex Solarstate Control, type SSH-1. The control employs a 'low-frequency switching shunt' technique which does not introduce a voltage drop between the array and battery. The switching action takes place only when the battery has reached a preset voltage (14.5 volts for this unit). The switching frequency varies from 2 - 2000 Hz. The SSH-1 has temperature compensation of -0.020 V/^{o}F referenced to 75^{o}F, therefore if temperatures were averaging -5^{o}C, the output voltage will be 15.5 +/- 0.1 volts.

3.2 Data Processing

Once each week T E S Limited remotely accesses the Water Resources department computer system and downloads the raw site data files into the PV monitoring database. The database is installed on a Compaq Deskpro 286 Computer System at T E S Limited and is set up using the dBASE III plus software package. Each parameter has one value for every hour. The parameters and their data type are listed in Table 1.

The raw numbers are converted to engineering unit values using one of two methods, depending on the data type. The analog type numbers are multiplied by a gain factor and added to an offset. The count type numbers must first be converted to counts/hr by subtracting successive hour readings and then scaled to give the engineering unit values.

Once the engineering unit data file has been created from the raw data, the daily and hourly data files are generated. These files contain minimum, maximum, average and standard deviation values for any given month. From these files a series of tables and graphs comparing temperatures, solar insolation, voltages and charge levels are produced. An example of the tables and graphs are contained in Appendix B.

These tables and graphs are used to generate a monthly report. This report along with an MS-DOS compatible 5 1/4 inch diskette containing the engineering unit data is available from the Solar Energy Development Program, Renewable Energy Branch, Energy, Mines and Resources Canada.

4.0 RESULTS AND DISCUSSION

This section of the report reviews the observed operating data and resulting trends. Where there is a deviation from the norm expected, potential causes or explanations are presented.

Each site has four performance parameters which can be evaluated, these are:

1) Solar Insolation (hourly and daily), 2) Temperatures (ambient, DCP and PV panel, 3) Electrical system (charge, discharge and efficiency) and 4) amount of data reported versus time in the reporting period.

4.1 Coppermine River

The measured Horizontal and Vertical Solar Insolation are compared to the published Atmospheric Environment Service (AES) data in graphs 1 to 4. (Note: AES data is for Inuvik UA, the closest AES site, located at 68^{o}N, 133^{o}W). As shown by the graphs, the recorded energy has followed the AES averaged energy. In addition, horizontal energy did surpass the vertical energy during June as was expected, due to the altitude angle of the sun.

Site average temperatures are shown in graphs 9 and 10 and for the monotoring period can be seen to vary from -32^{o}C to +18^{o}C. Graph 9 shows the possible effect of having a darkly coloured PV Panel assembly since the PV panel temperature was always measured to be higher than the ambient temperature during daylight hours. Also of note is the time lag of the DCP temperature behind the solar panel temperature. This is to be expected due to the large thermal capacity of the concrete platform.

Due to the apparent failure of the charge resistor voltage sensor, charge efficiency for this site can not be accurately calculated Although, the actual amount of battery charge energy is not known, the system was seen to be charging as the battery voltage (graphs 7 and 8) has risen over the course of the past six months.

As can be seen in graph 6, the discharge energy has a peak every third hour. This peak is caused by the satellite transmission of data every third hour. The transmitter draws 3 amperes of current for a 30 second time period. Also seen in the data of graph 6 is a drop in the discharge curve starting at the sixth hour of the day and the rise at the eighteenth hour. This drop in the curve corresponds to the increase of solar energy during this period and has been attributed to electrical interference between channels within the V-F circuitry.

Of the 5808 calendar hours available for monitoring between November 1 and June 30, only 3227 hours (56%) of data were received at T E S Limited. This "lost" data reduces the integrity of the data. Some additional data have been recovered by Environment Canada during the production of this Final Report. These data have been retroactively entered into the database and some reduced data presented for comparison purposes in Appendix "D".

The data can be lost in one of two ways: either Washington does not receive the satellite transmission from the site or Environment Canada Hull does not receive the data from Washington. The site datalogger is programmed to collect data for a three hour period then transmit this data to Washington via satellite. Once the data is transmitted by the datalogger, it is erased. Since the satellite transmission is a one way communication link, if Washington does not receive the data (one reason would be if the datalogger missed its transmission window) there is currently no mechanism to allow commands to be transmitted to the datalogger to request a retransmission. Once Washington captures the data, it is held for only 24 hours. If the Water Resources Branch computer system fails to collect this data, via telephone lines, the previous 24 hours of data can be lost. There are many different and varied reasons as to why the data may not be collected from Washington but a computer system failure appears to be the most common recurring problem.

4.2 Lake Diefenbaker

The measured Horizontal and Vertical Solar Insolation are compared to the

published AES data in graphs 12 to 15 (Note: AES data is for Swift Current CDA, the closest AES site, located at 50°N, 118°W). As shown, the recorded energy has followed the expected AES trends. It was observed that during April, May and June the Horizontal mean daily solar energy was greater than the vertical energy. This trend would be expected to continue until October. Graphs 11 and 13 show an unexpected trend, this is, the vertical curve is lagging the horizontal curve. This was discussed with the site operators and it was found that due to an electrical generating station close by, the actual PV panel orientation cannot be verified by the use of a compass. Therefore, it is highly possible that the panel is facing to the west of due south.

As can be seen in the charge and discharge graphs, the batteries continued to charge through the report period. Although charge efficiency was expected to drop during the period, due to the battery reaching full charge level, the efficiency remained at an almost constant 8% during daylight hours. It was estimated that if all this energy (approximately 1 MJ per month) is being absorbed by the batteries, the acid in the batteries should be boiling. After discussions with the site operators, it was found that the servo manometer was connected directly across the battery terminals and therefore the load current was not included in the previously calculated discharge energy. Assuming that the servo manometer runs approximately 1 hour a day at 350 mA, it would consume 550 KJ per month.

Therefore, if we now account for the energy used to power the servo-manometer, the battery charge level of graph 23 results. The graph shows the batteries approximately 16% overcharged. It is to be noted that a certain amount of battery overcharging is necessary to ensure that there is no vertical concentration gradient of sulphuric acid (stratification) on the battery electrodes. Battery manufacturers generally recommend that the normal amount of overcharging required be in the range 15% to 20%.

A noticable difference can be noted in the performance of the two sites' voltage regulators where the battery voltage is seen to rise at Coppermine River while the battery voltage is seen to fall at Lake Diefenbaker. For

both sites the battery voltage is limited by the operation of the voltage regulator. The Coppermine River regulator is a 14.5V zener diode. As the battery voltage during the monitoring period started at a low of 12 volts, nc regulator shunting action would occur until the battery voltage increased by 2.5 volts. Graph 7 shows that the battery never reached a voltage sufficient to cause the 14.5V zener to conduct.

The regulator at the Lake Diefenbaker site is, however, a solid state device with a negative temperature compensation. That is, as the temperature of the regulator rises the regulating voltage will drop. At this site, since the batteries were at full charge at the beginning of the program, the regulator controlled the battery charge by shunting the panel voltage during the daylight hours giving an apparent decrease in panel voltage (see Appendix C). Therefore, as the average daily temperature was rising, the voltage and average battery voltage can be seen to be dropping during the period monitored by this report.

As with the Coppermine River site, the percentage of valid data is low. Of the 3000 calendar hours available (February 26 to June 30), only 1864 hours (62%) of data were received at T E S Limited.

Site temperatures are shown in graphs 20 and 21, and as with Coppermine River, the panel temperature was higher than the ambient during the day. Also, the DCP temperature lagged the ambient temperature, again due to the DCP's large thermal capacity (Note: After discussions with the site operator, it was found that the ambient and panel temperature probes were interchanged. This report compensates for this, but the monthly reports do not. Therefore, the monthly reports show the ambient temperature rising above the panel temperature during the daylight hours.)

5.0 CONCLUSIONS

The program objectives were met and the Photovoltaic Monitoring Database has provided EMR with operating data and site performance logs of two operational PV sites.

The database was established on an IBM-PC compatible computer, using the commercially available database dBASE III and T E S Limited developed, user application programs. Since the data is IBM-PC compatible, it is readily available to others for independent study. The database has been set-up for easy expansion. In addition to the database, a monthly report format has been developed which gives the user a brief account of each sites' equipment and site activity, and summarizes the site performance records in a series of graphs and tables.

Currently, the data retrieval system will allow continuous collection of data from isolated sites. However, due to the percentage of "lost" data, an improvement in the method of data collection should be established to decrease the amount of lost data or a more frequent method of data acquisition be established between the satellite and ground station or between Washington and Environment Canada. (See Appendix "D" for discussion on the additional data recovered from Environment Canada.)

As stated previously, the data can be lost during the datalogger-to-satellite-to-Washington link or during the Washington-to-Hull link. In both cases communication is one way. If for example. the datalogger misses its satellite transmission window, Washington cannot request a retransmission and the missed three hour block of data is lost. Environment Canada, Hull, collects the data from Washington via modem, on a daily basis, but the computer system operators only enter the data into their database on a weekly basis. Therefore, if the program that automatically dials up Washington fails for any reason, the database operators will not discover the failure until they try to enter the data into the database. By this time the data is no longer available from Washington as they only store the data for a 24 to 48 hour period. After reviewing all of the data available from Hull, it has been concluded that

greater than 90% of the lost data is lost in the Washington-to-Hull link.

Two alternatives to the current method of data transfer are direct dial and manual retrieval. If the site is accessible by telephone, a modem could be installed and the database would automatically interrogate the datalogger on a regular basis. If the site is not accessible by phone, the datalogger could be equipped with a mass storage device and on a regular basis a site operator would collect the data. Different types of storage devices are available and each site may require something different because of the environment. Possible storage devices are:

a) Magnetic Tape - can store a high volume of data but not recommended for harsh environments

b) Memory Modules (e.g. bubble memory, non-volatile ram) - can store a medium amount of data and can be designed for rugged environments but have a high cost

c) Printer - can store high volume of data, have a low cost, and can operate in harsh environments but data processing (reading from printout and entering into database) is time consuming and uneventful - if a bar code is printed as opposed to numbers, data processing could be greatly simplified.

The battery charge level for each site is calculated using energy balances. This method of estimating battery charge can be misleading

Due to a sensor failure in the charge current measuring circuitry at the Coppermine site, it was incorrectly predicted from the energy balance that the battery was failing. Other sensors in the system proved to the contrary, and the battery was indeed slowly charging. Similarly, due to insufficient site wiring information (extra loading on the battery, not measured by the system sensors) the energy balance incorrectly predicted

gross overcharging of the battery at Lake Diefenbaker. It has since been shown that due to a fixed load on the battery, the PV charging system is operating quite normally within the manufacturers design limits.

An overall conclusion is that the installation does work. The photovoltaic panel supplies a sufficient amount of energy to charge the batteries. This is proven by the fact that, at the Coppermine River site, the battery voltage as risen over period from November 1, 1986 to June 30, 1987 and at the Lake Diefenbaker site, the energy balance shows a net charge from February 26, 1987 to June 30, 1987.

6.0 RECOMMENDATIONS

After reviewing the received site data the following recommendations are submitted to Energy, Mines and Resources for consideration:

1. An improved method of data handling to increase the percentage of captured data.

2. The use of a "state of battery charge level" sensor/transducer to increase the accuracy of the reported battery charge level and improve the integrity of an energy balance report on site performance.

3. Additional instructions should be included in the Installation Procedures that will test and verify the operation of all sensors after installation.

4. Install the measurement sensors in such a way as to allow easy replacement.

5. Allow for system sensor redundancy where appropriate such that if one sensor fails, a derived value for the missing system parameter can be obtained from other system sensors.

6. More user feedback of data presented here to allow optimization of the database and add additional data channels where appropriate.

7. A second study should be conducted on two new sites that are closer together (less than 100 km apart) but on or near the same longitude as the Lake Diefenbaker (107^{o}W) or Coppermine River (115^{o}W) site. This would allow a better site comparison of four Northern sites and allow for a more meaningful comparison between the two voltage regulators types controlling identical PV equipment in similar environments.

7.0 REFERENCES

1. Becker, Dustin J., Lead-Acid Battery Charge Process in Photovoltaic Applications, IEEE Spectrum, April 1979.

2. Photovoltaic Monitoring Database Interim Report (C723-I), T E S Limited, 1987.

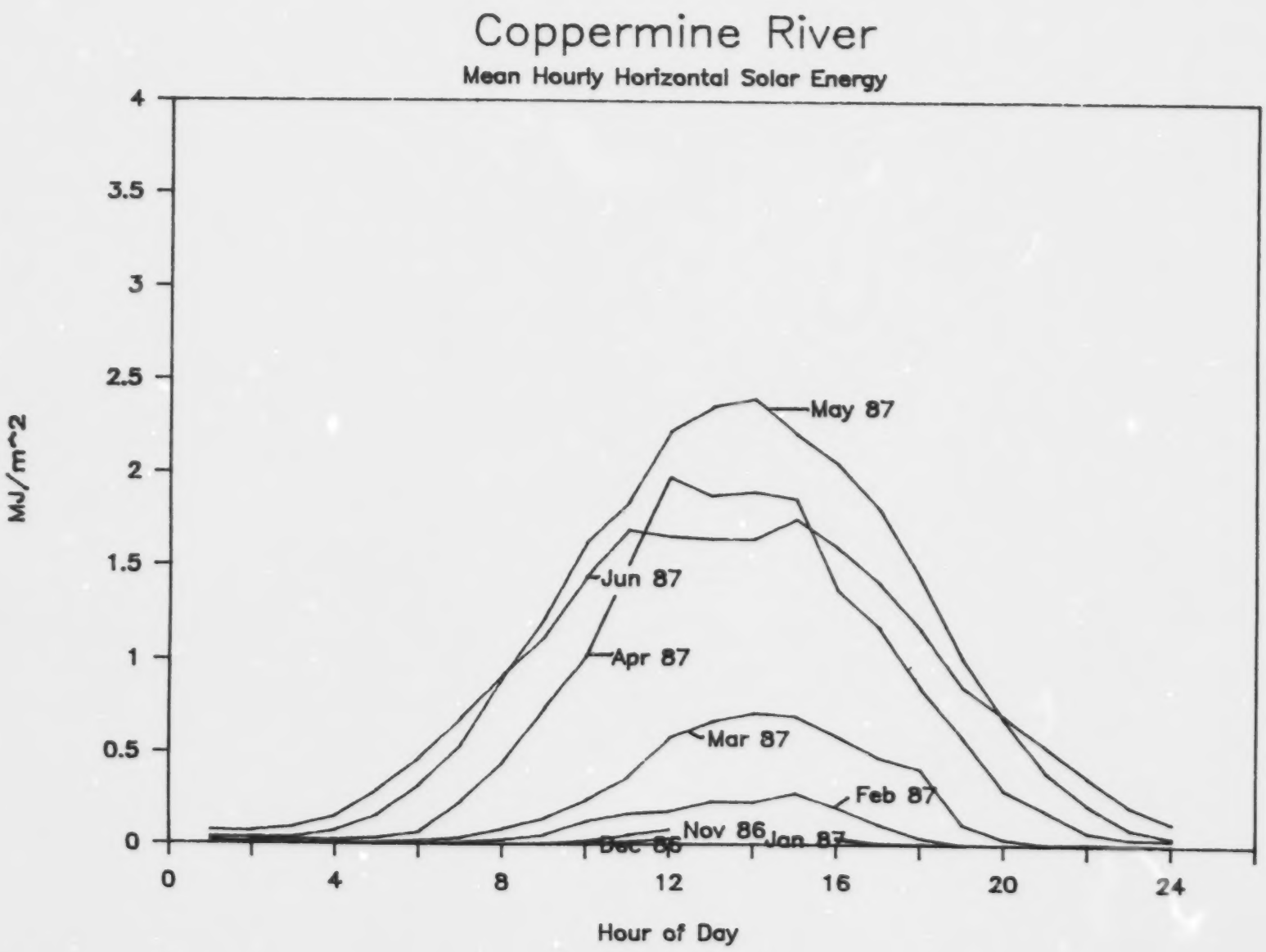
3. Photovoltaic Monitoring Database Site Data Report (C723-1, C723-2, C723-3, C723-4, C723-5, C723-6), T E S Limited, 1987.

APPENDIX "A"

Copperwine River Site Data Summary Reports

1987

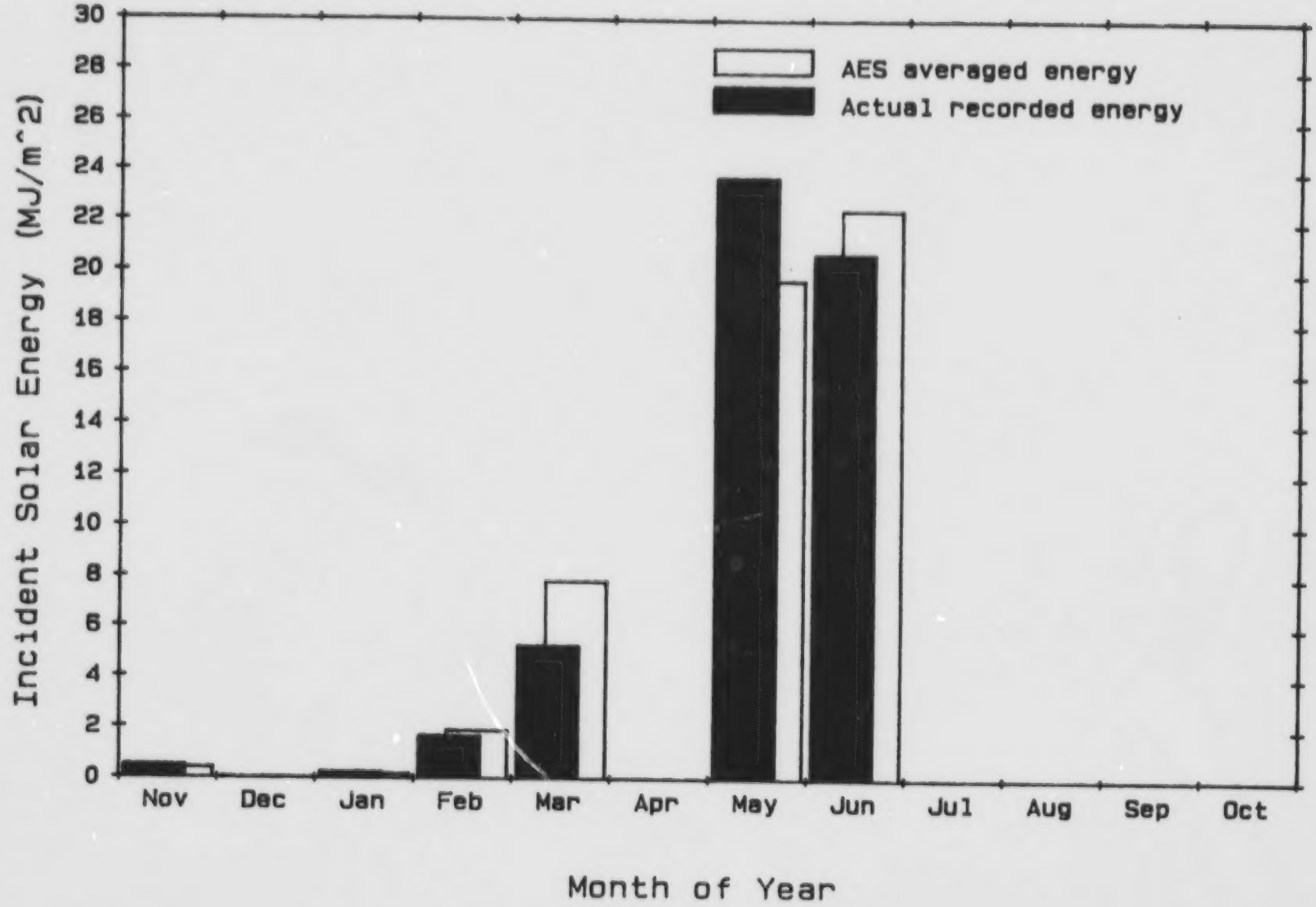
GRAPH 1


Coppermine River
Mean Hourly Horizontal Solar Energy
MJ/m^2
4
3.5
3
2.5
2
1.5
1
0.5
0
0
4
8
12
16
20
24
Hour of Day
May 87
Jun 87
Apr 87
Mar 87
Feb 87
Nov 86
Jan 87
Dec 86

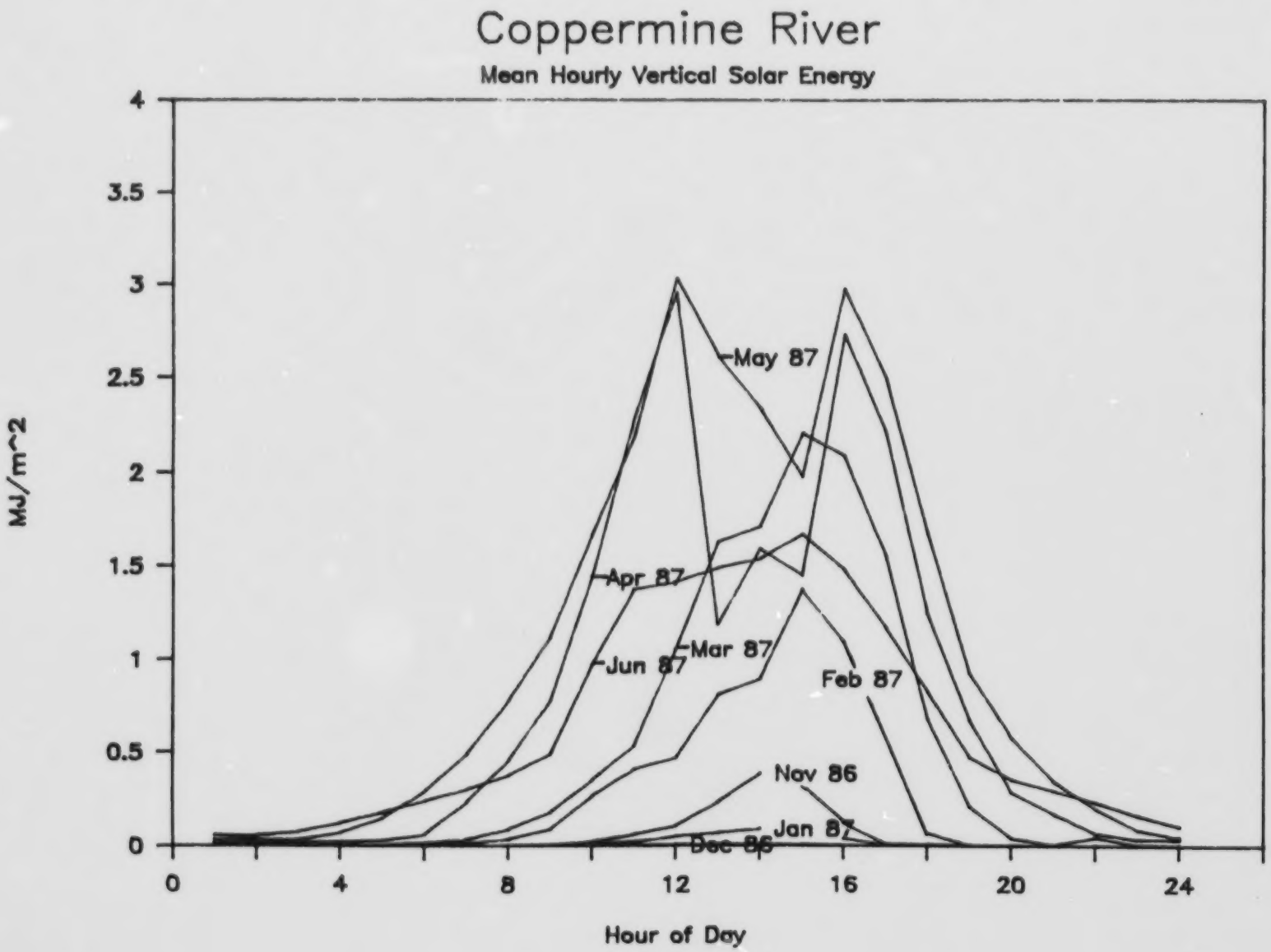
GRAPH 2

Mean Daily Horizontal Solar Energy

Coppermine River 1986/1987



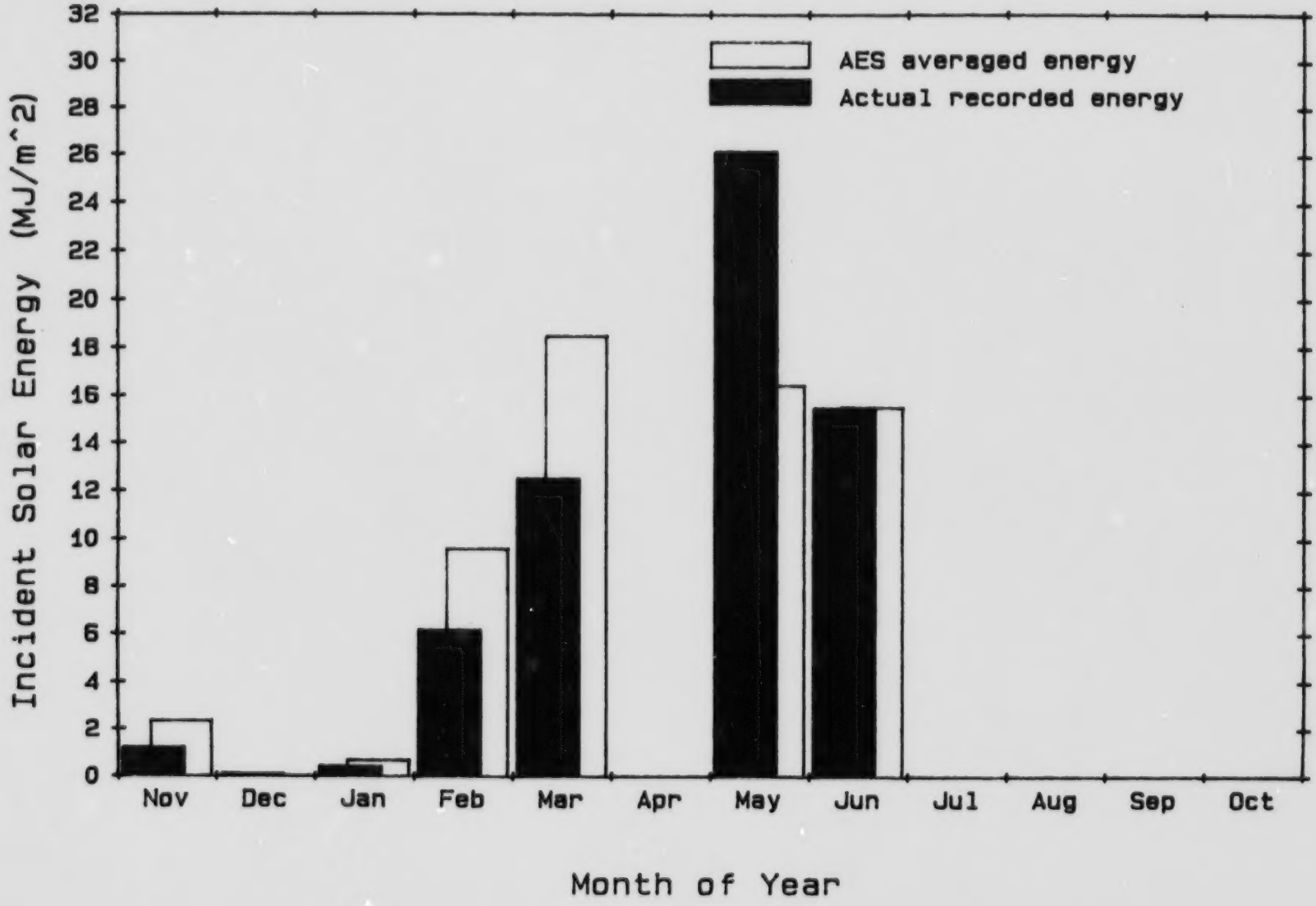
GRAPH 3


Coppermine River
Mean Hourly Vertical Solar Energy
MJ/m^2
4
3.5
3
2.5
2
1.5
1
0.5
0
0
4
8
12
16
20
24
Hour of Day
May 87
Apr 87
Mar 87
Jun 87
Feb 87
Nov 86
Jan 87
Dec 86

GRAPH 4

Mean Daily Vertical Solar Energy

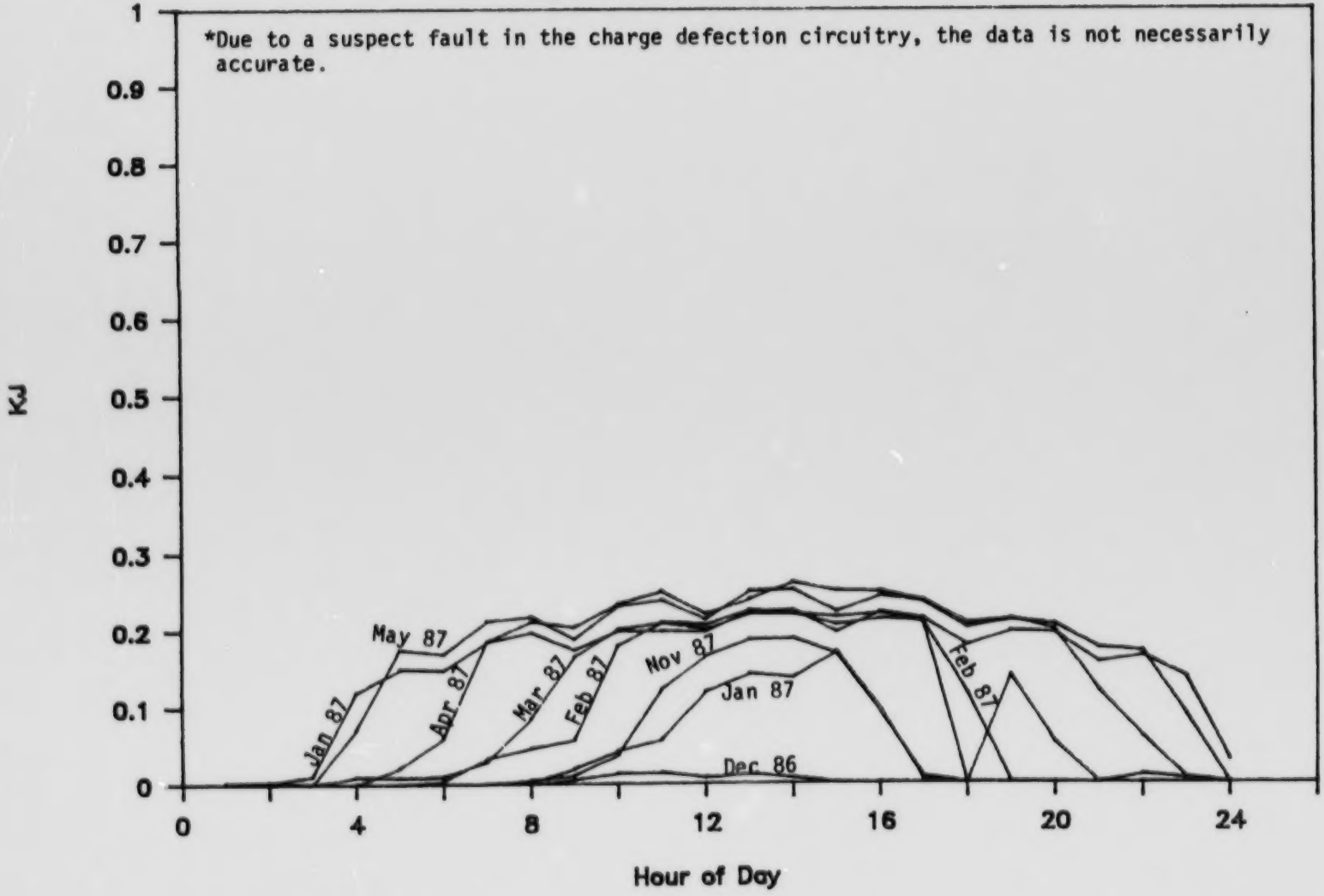
Coppermine River 1986/1987



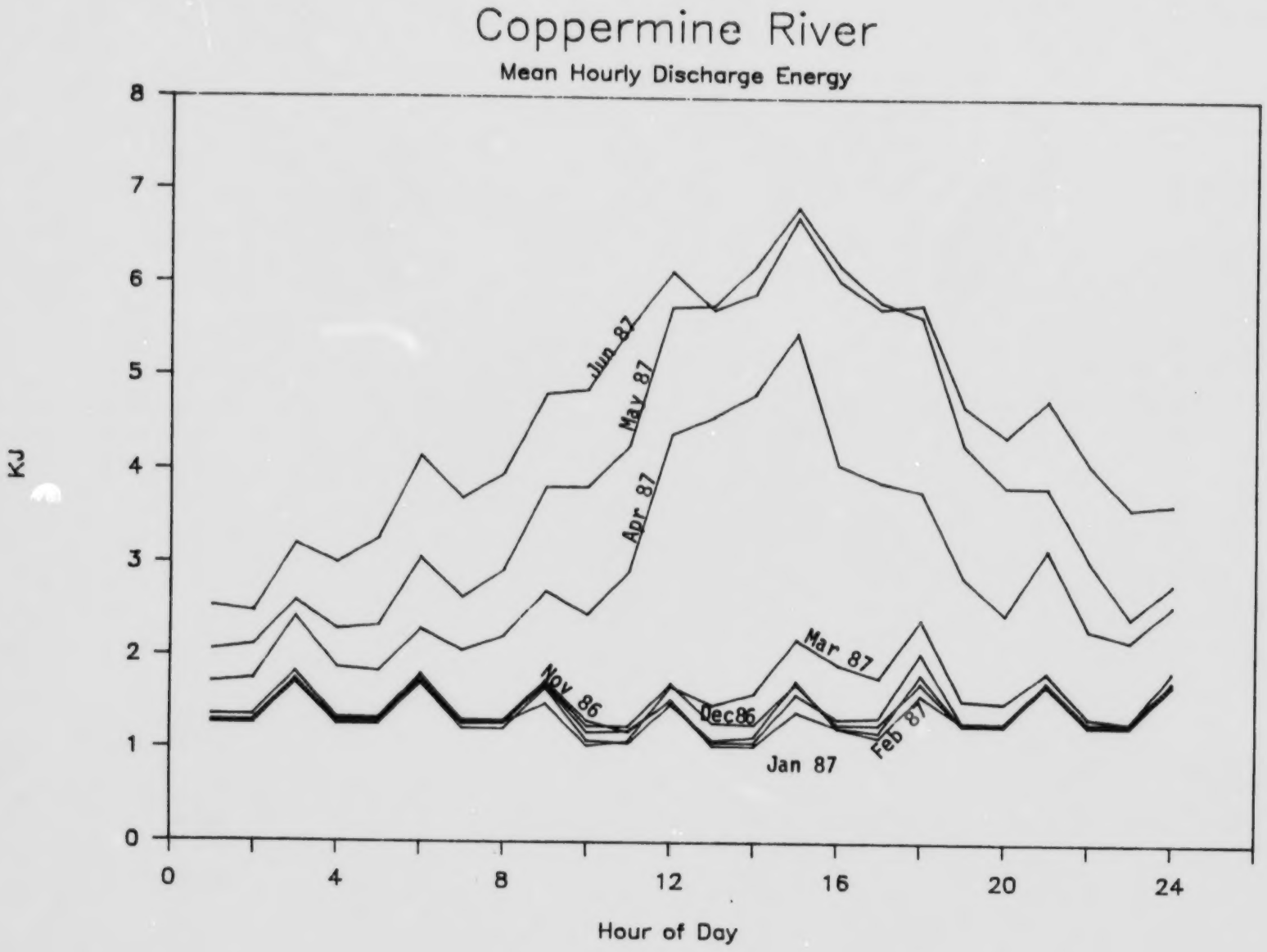
Graph 5

Coppermine River

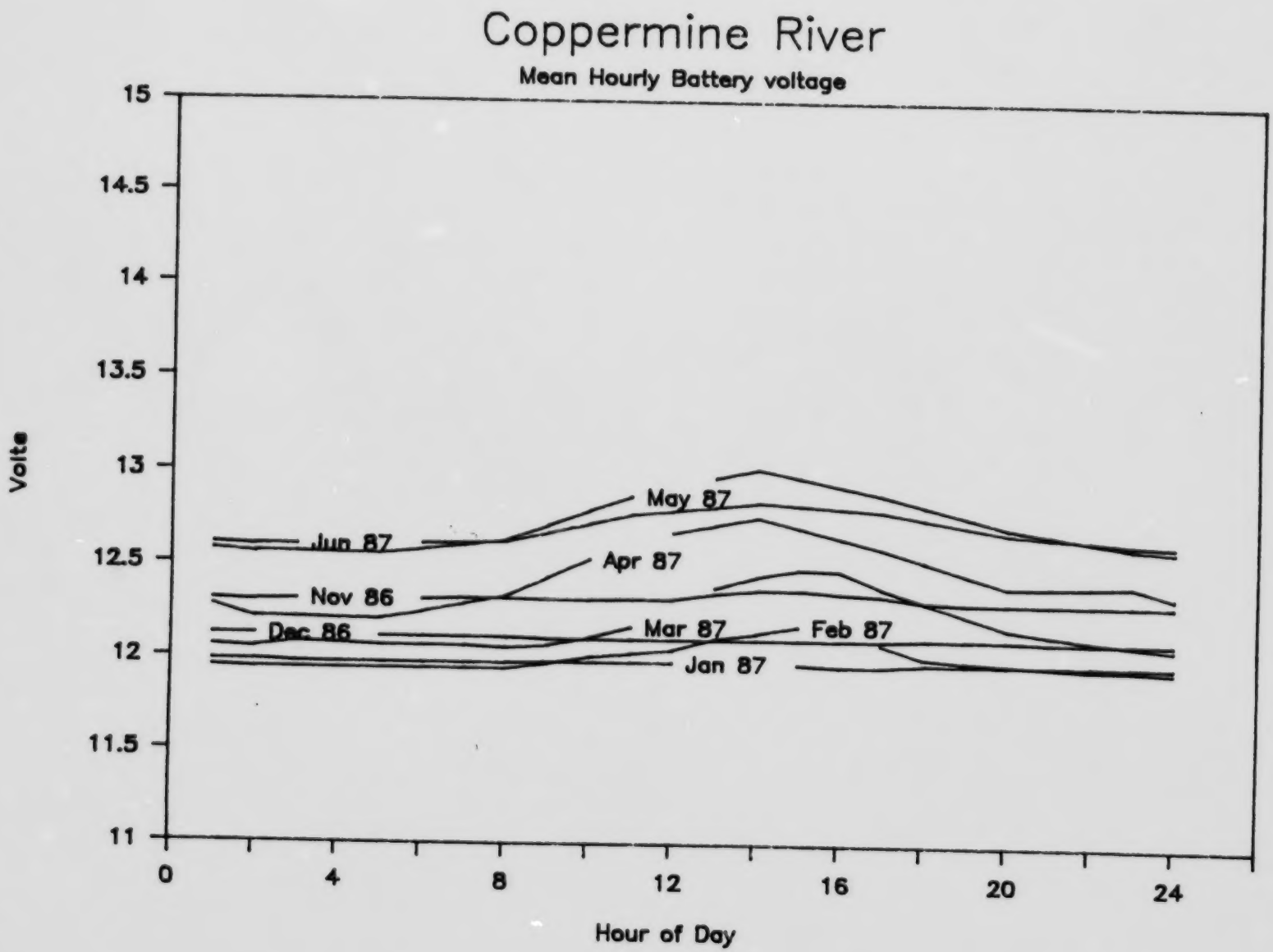
Mean Hourly Charge Energy



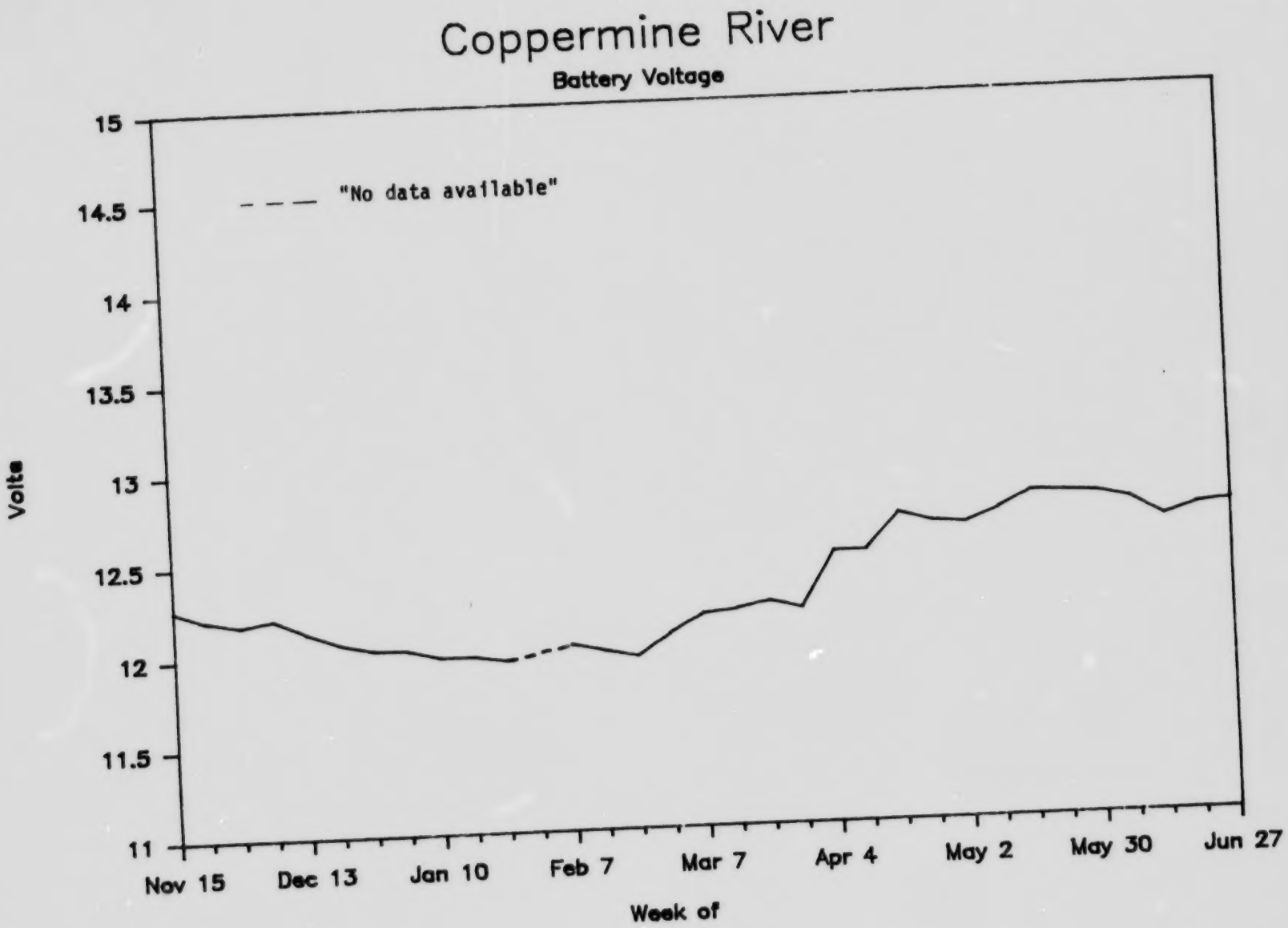
Graph 6


Coppermine River
Mean Hourly Discharge Energy
KJ
8
7
6
5
4
3
2
1
0
0
4
8
12
16
20
24
Hour of Day
Jun 87
May 87
Apr 87
Mar 87
Nov 86
Dec 86
Jan 87
Feb 87

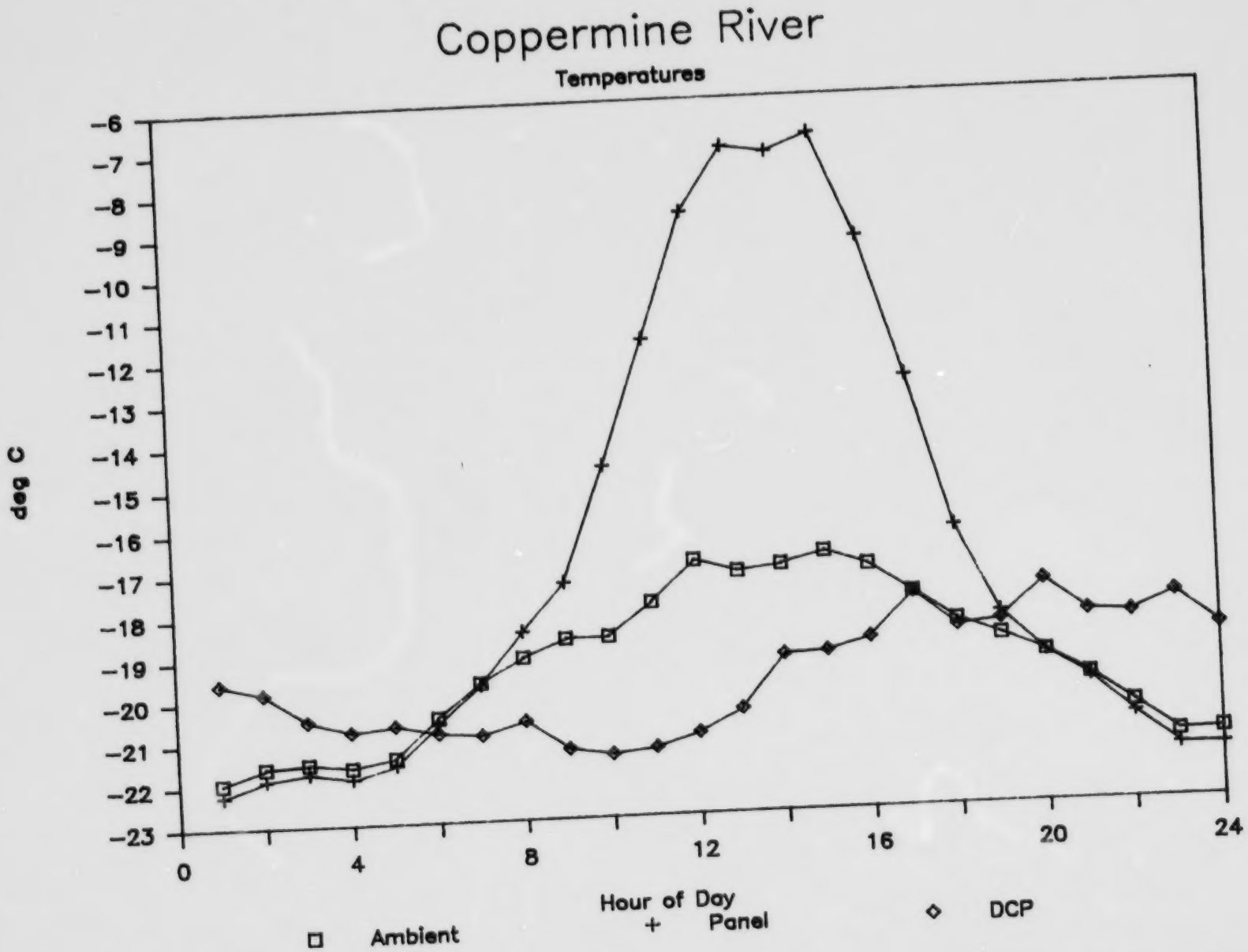
GRAPH 7


Coppermine River
Mean Hourly Battery voltage
Volts
15
14.5
14
13.5
13
12.5
12
11.5
11
0
4
8
12
16
20
24
Hour of Day
May 87
Jun 87
Apr 87
Nov 86
Dec 86
Mar 87
Feb 87
Jan 87

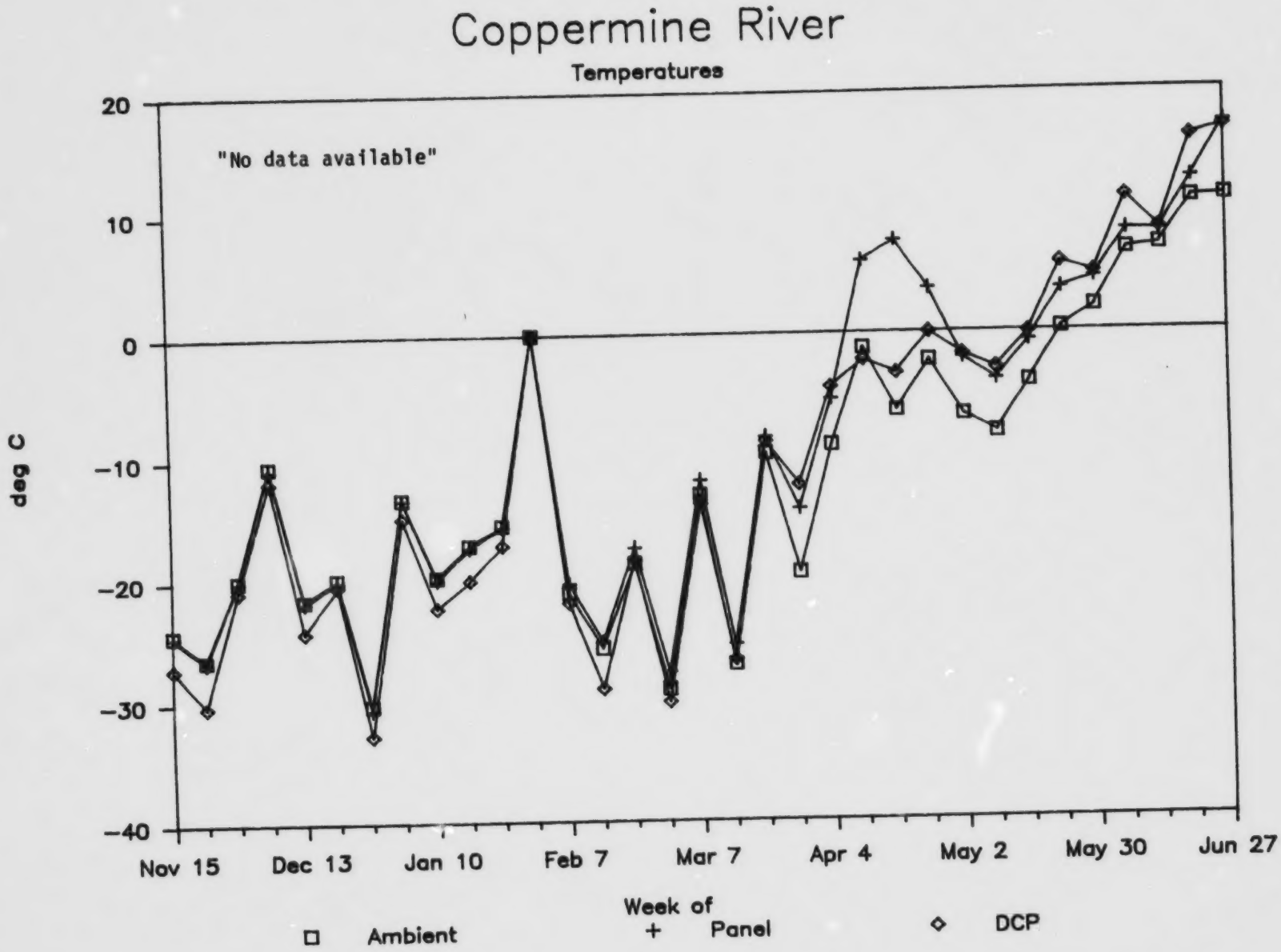
GRAPH 8


Coppermine River
Battery Voltage
"No data available"
Volts
15
14.5
14
13.5
13
12.5
12
11.5
11
Nov 15
Dec 13
Jan 10
Feb 7
Mar 7
Apr 4
May 2
May 30
Jun 27
Week of

GRAPH 9


Coppermine River
Temperatures
deg C
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
-16
-17
-18
-19
-20
-21
-22
-23
0
4
8
12
16
20
24
Hour of Day
Ambient
Panel
DCP

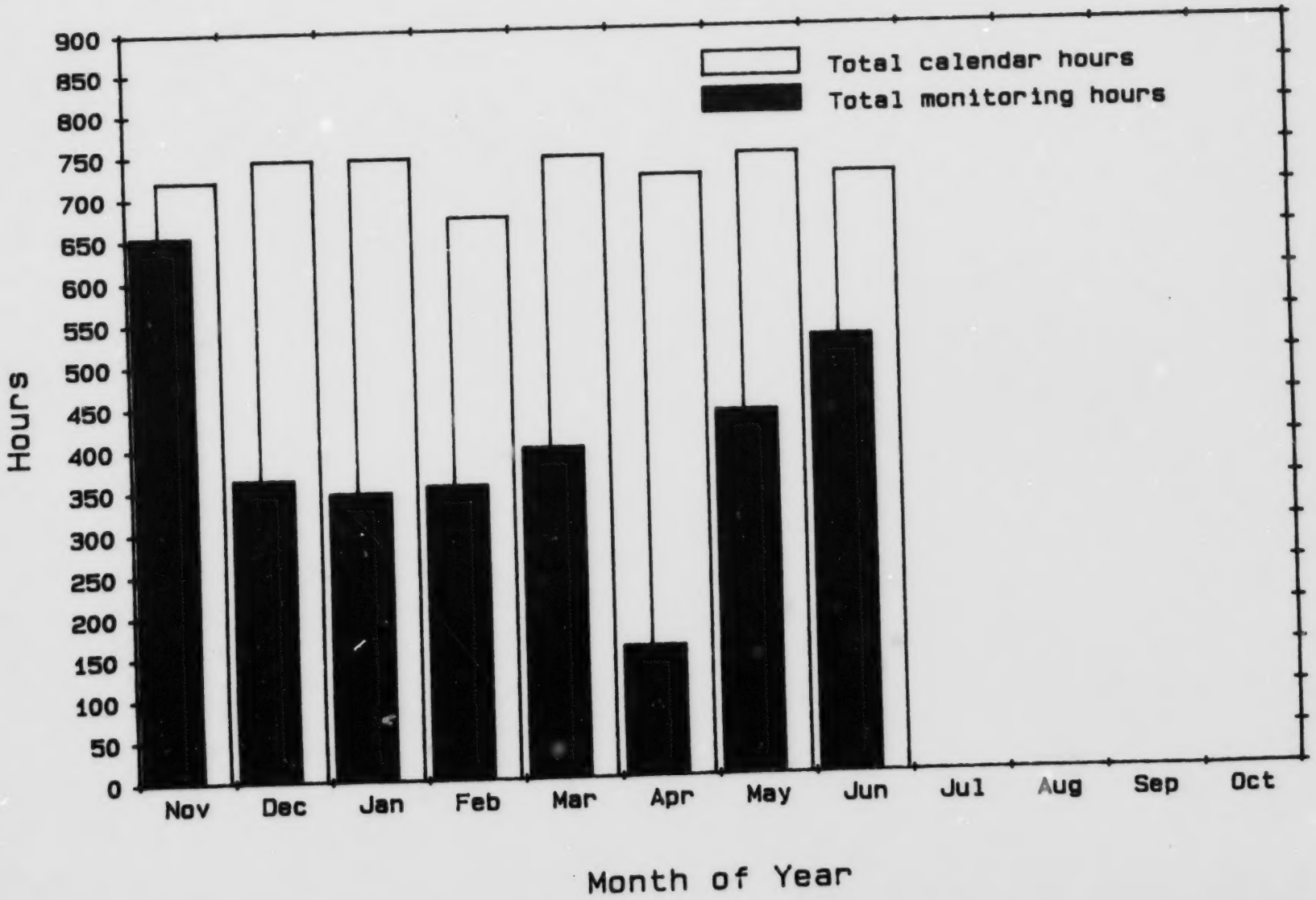
GRAPH 10

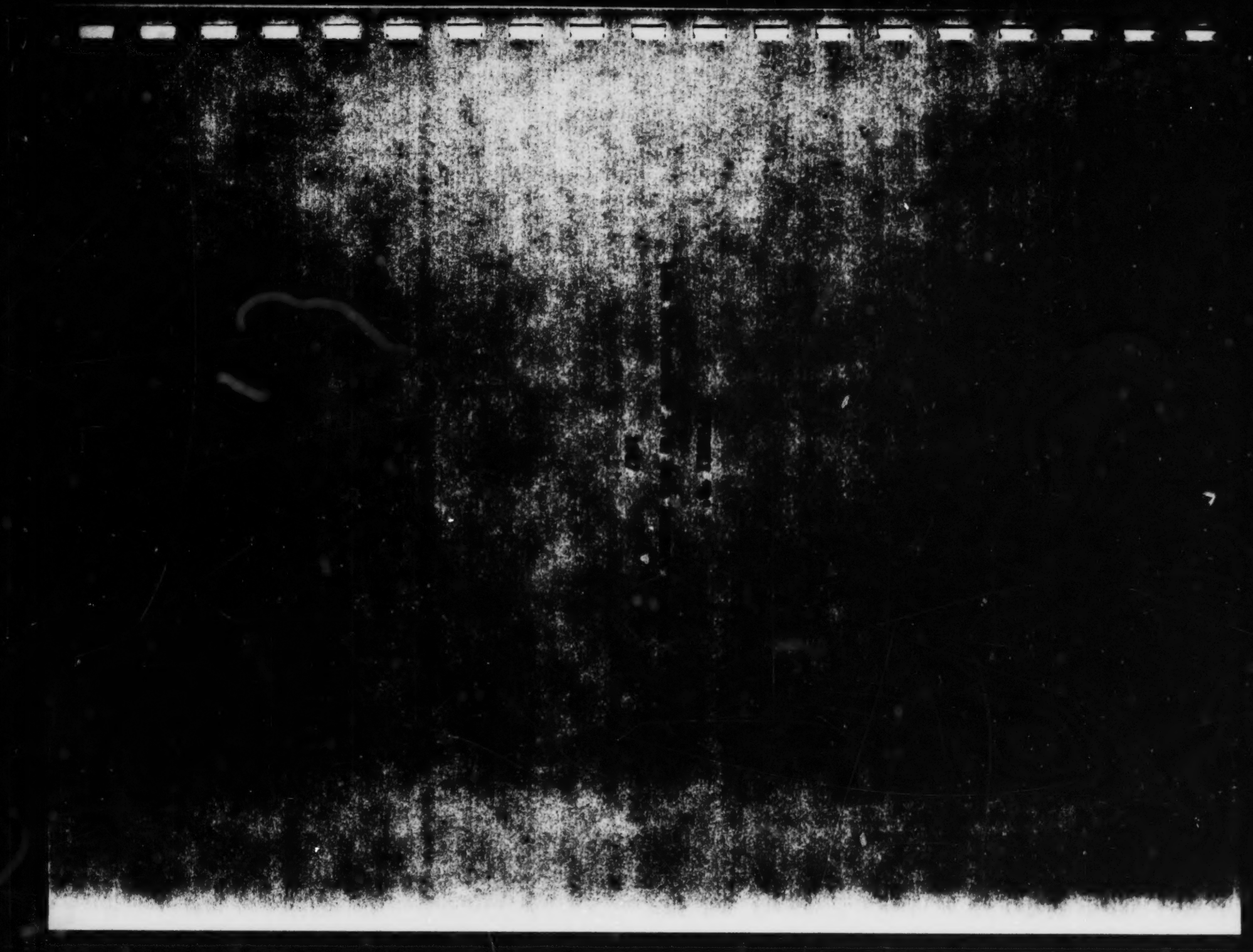

Coppermine River
Temperatures
"No data available"
20
10
0
-10
-20
-30
-40
deg C
Nov 15
Dec 13
Jan 10
Feb 7
Mar 7
Apr 4
May 2
May 30
Jun 27
Week of
Ambient
Panel
DCP

GRAPH 11

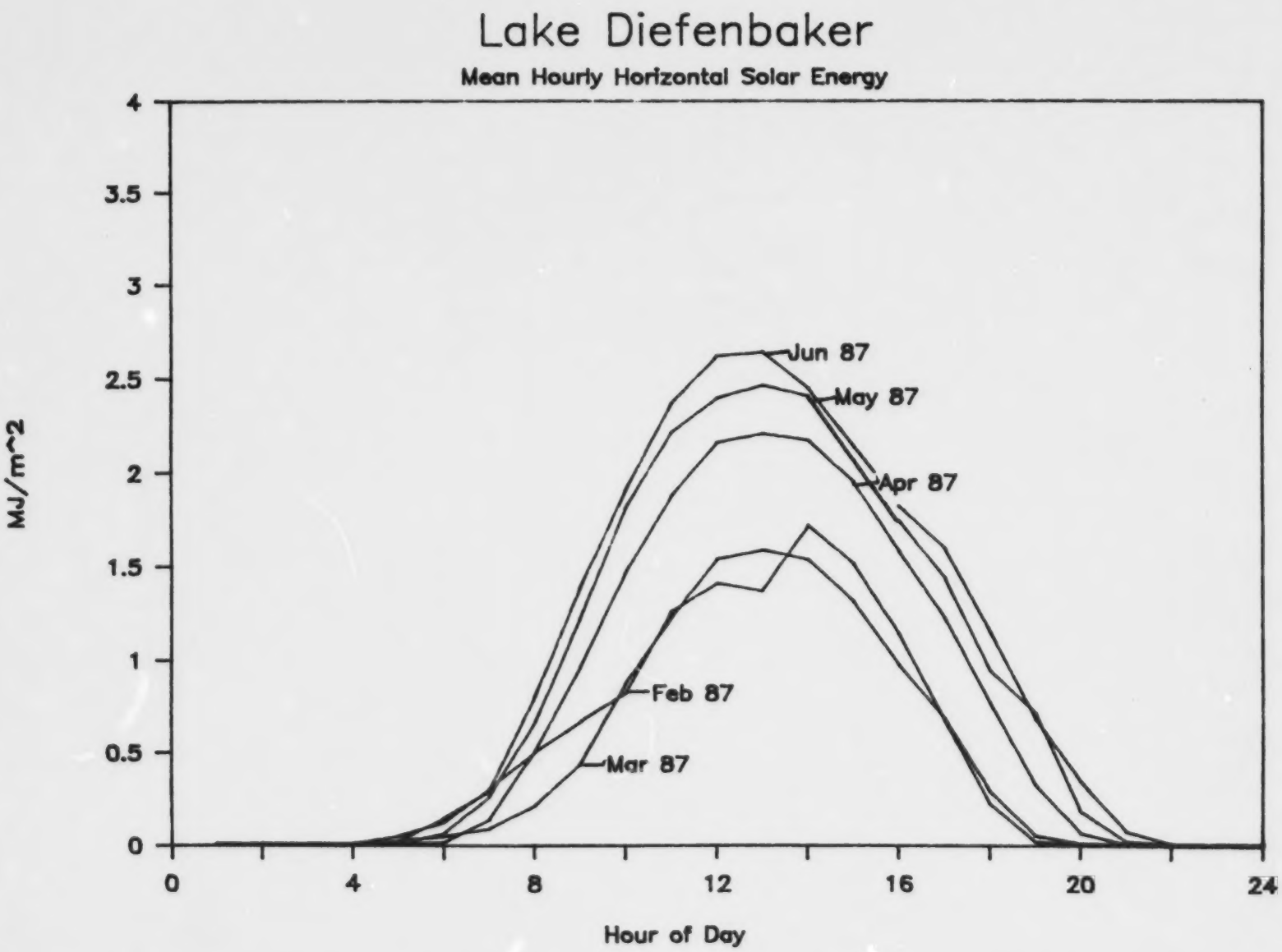
Calendar Hours vs. Monitoring Hours

Coppermine River 1986/1987





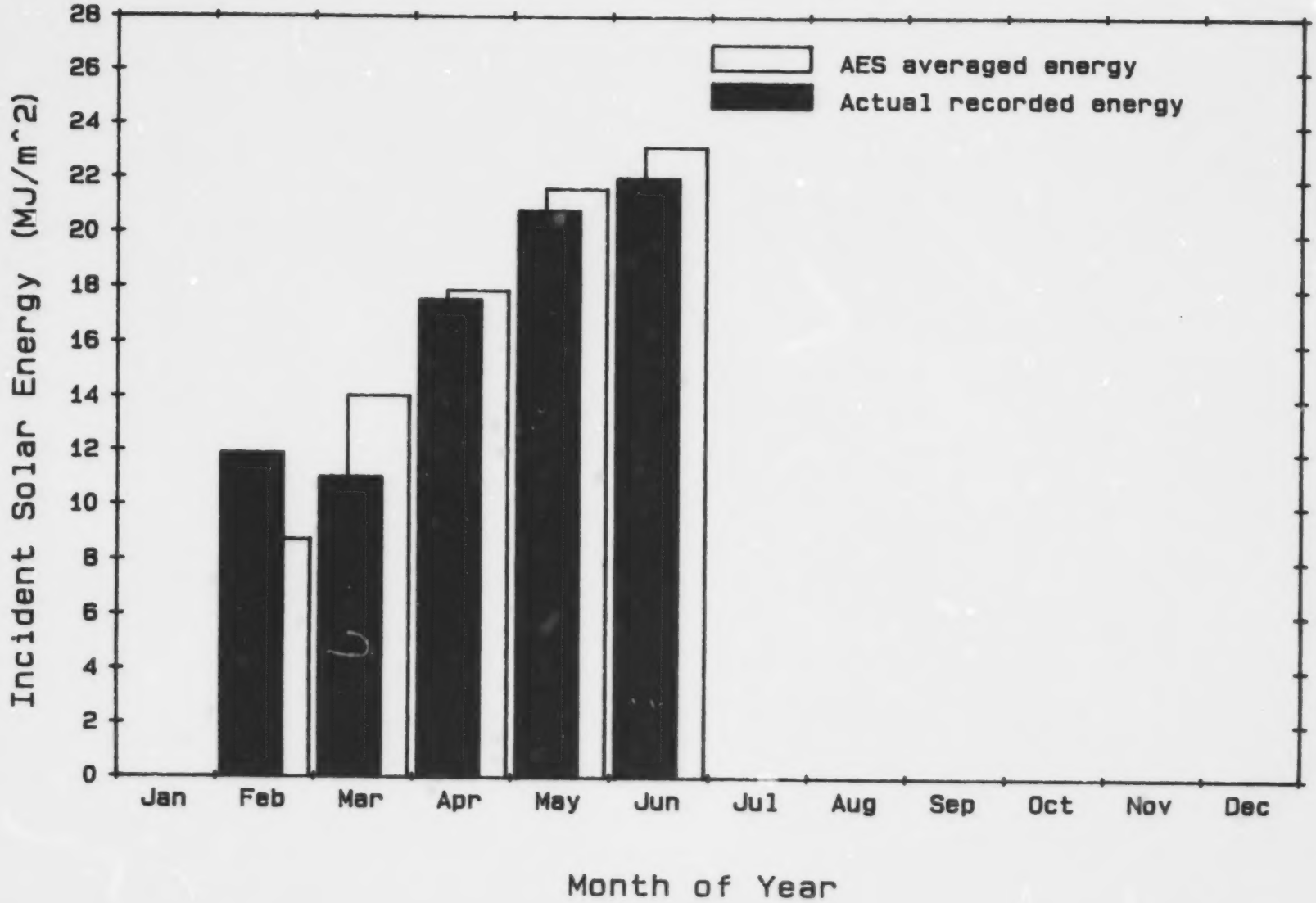
GRAPH 12


Lake Diefenbaker
Mean Hourly Horizontal Solar Energy
MJ/m^2
4
3.5
3
2.5
2
1.5
1
0.5
0
0
4
8
12
16
20
24
Hour of Day
Jun 87
May 87
Apr 87
Feb 87
Mar 87

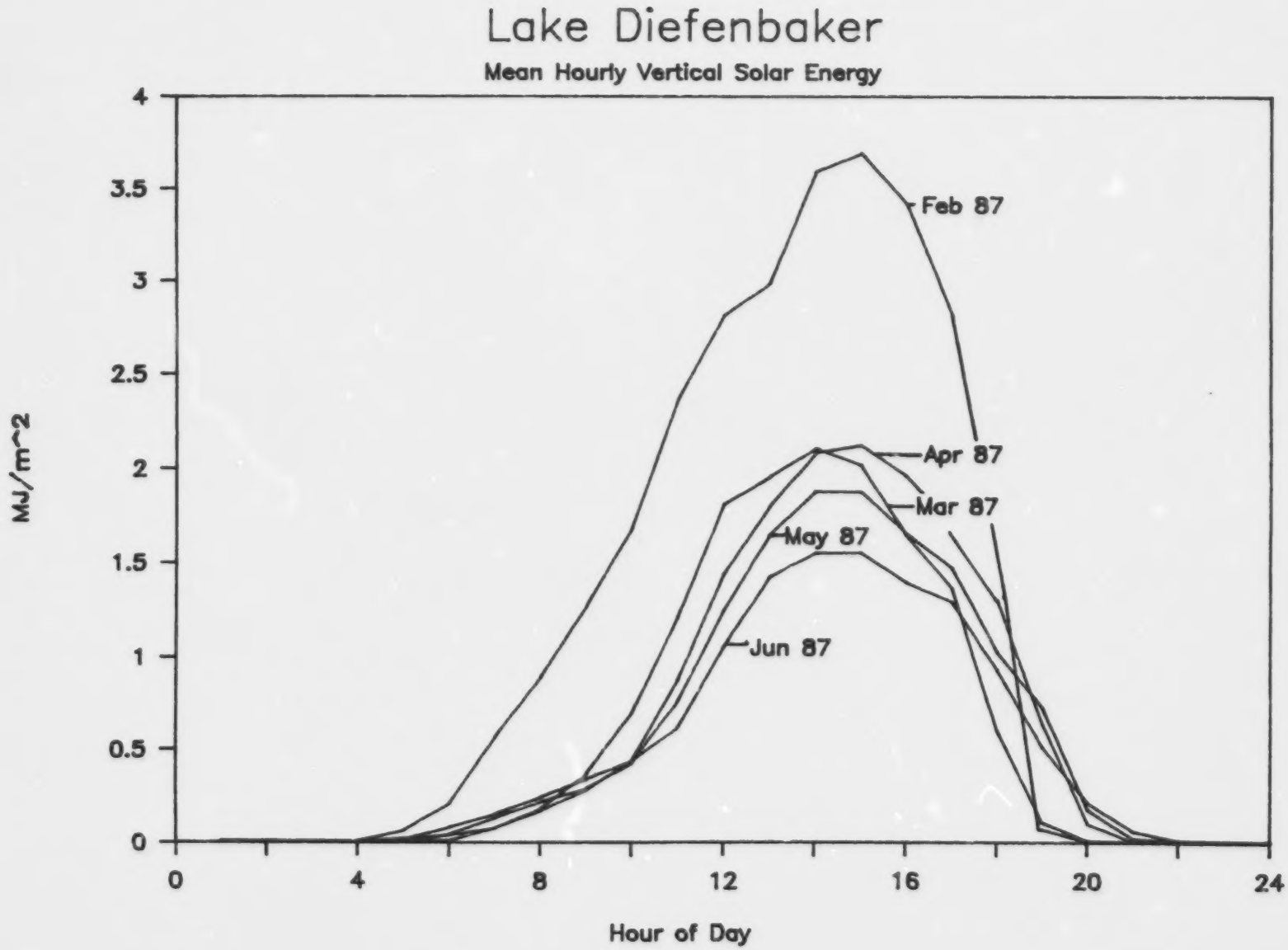
GRAPH 13

Mean Daily Horizontal Solar Energy

Lake Diefenbaker, 1987



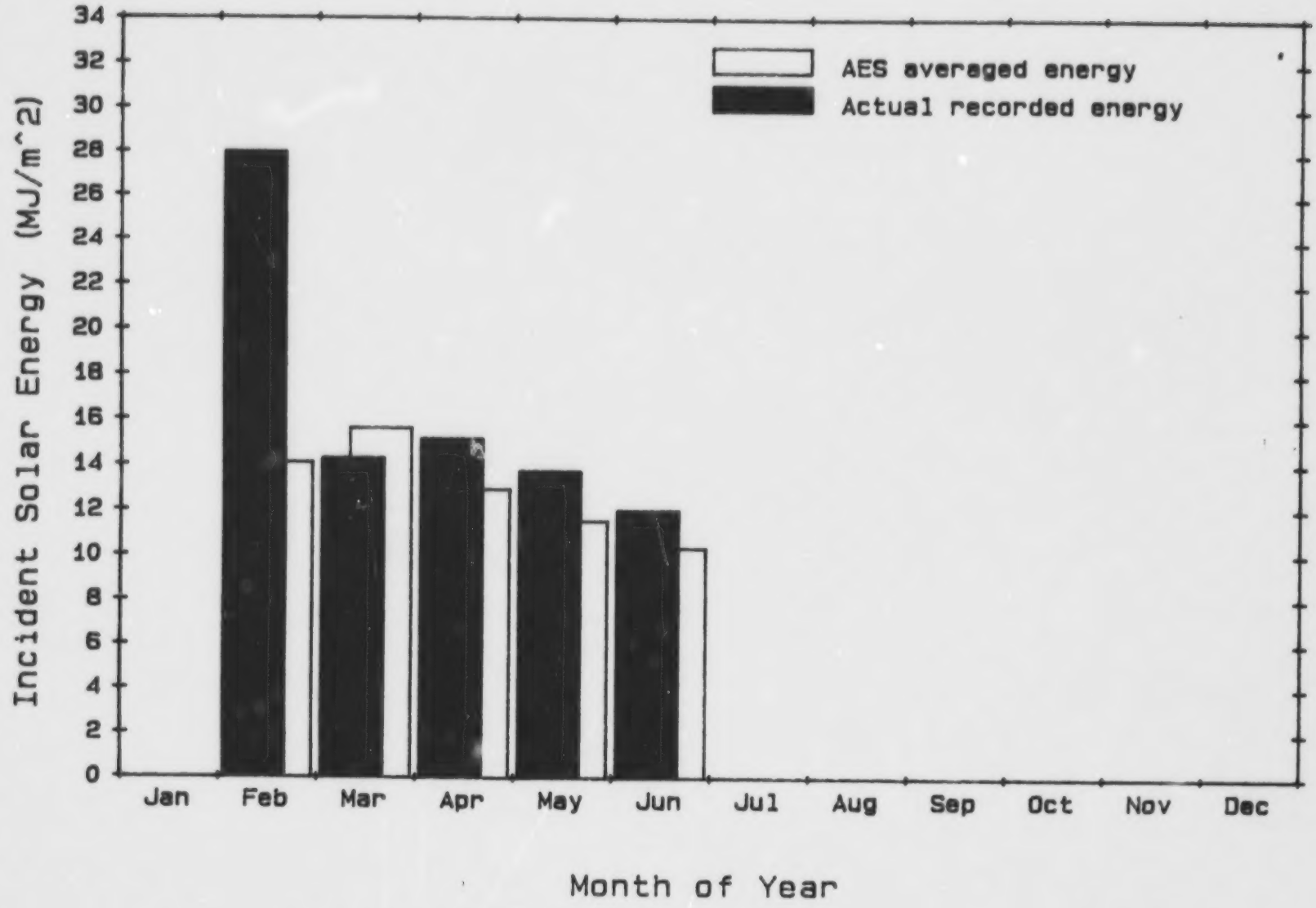
GRAPH 14


Lake Diefenbaker
Mean Hourly Vertical Solar Energy
MJ/m^2
4
3.5
3
2.5
2
1.5
1
0.5
0
0
4
8
12
16
20
24
Hour of Day
Feb 87
Apr 87
Mar 87
May 87
Jun 87

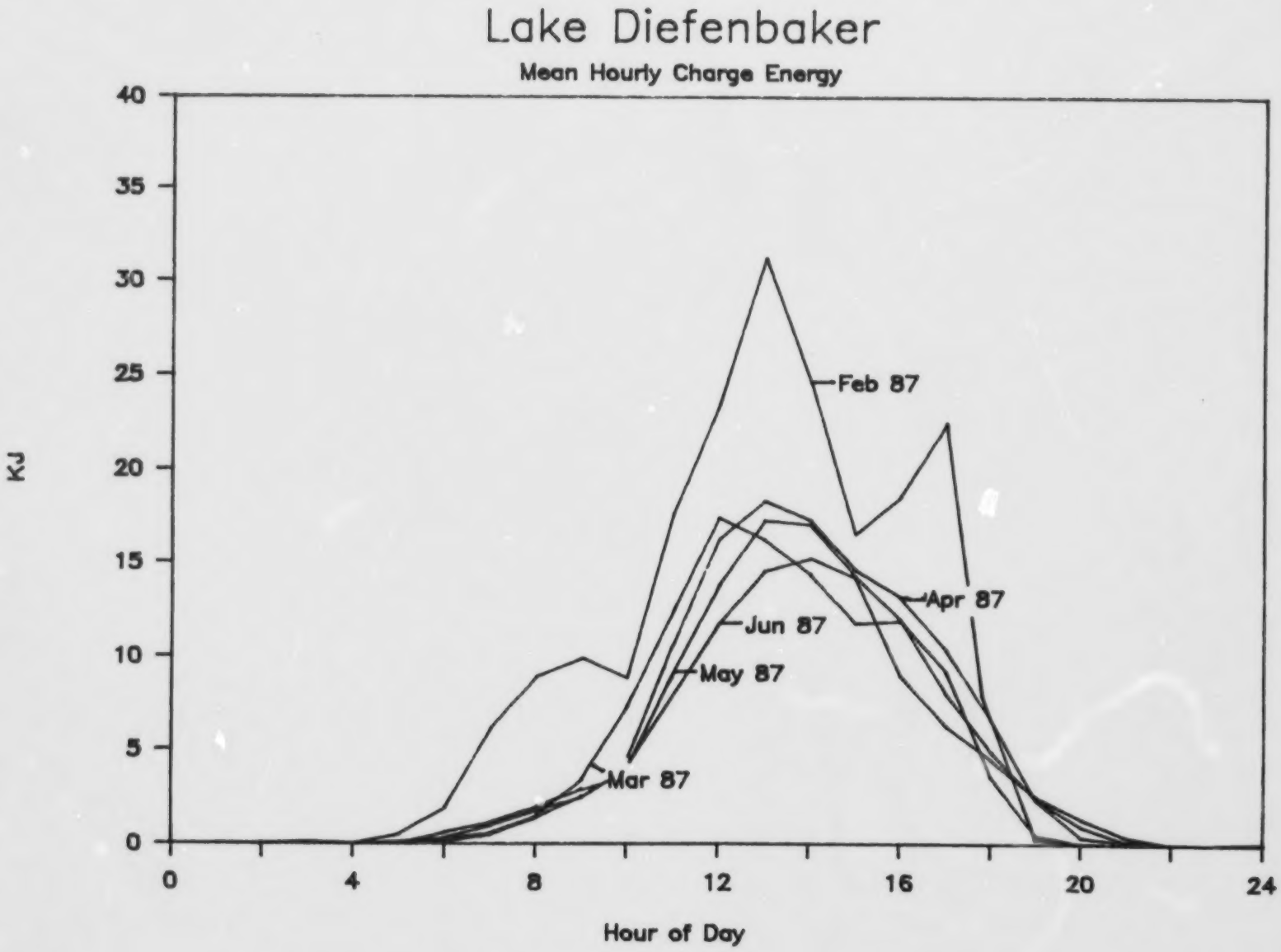
GRAPH 15

Mean Daily Vertical Solar Energy

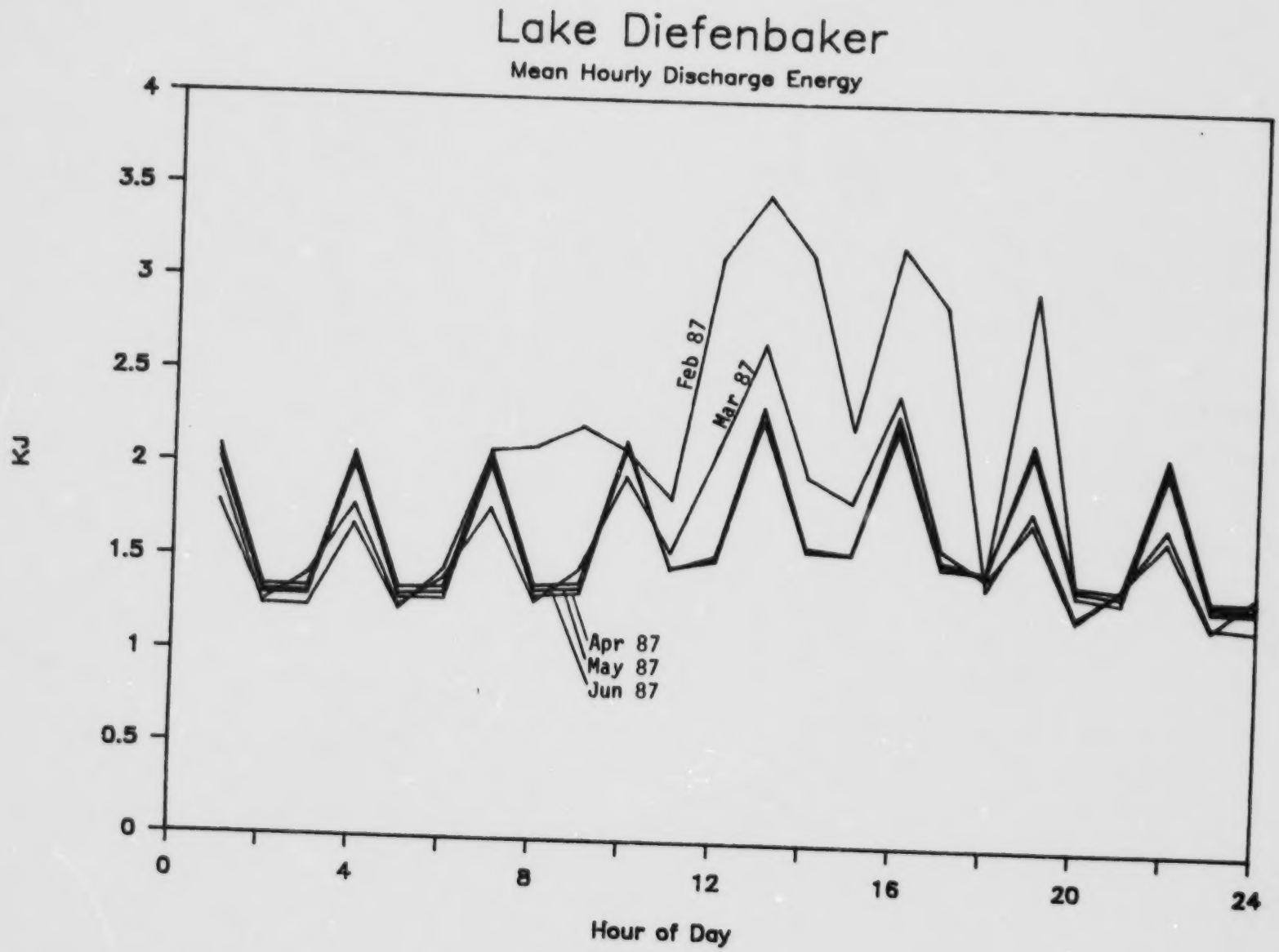
Lake Diefenbaker, 1987



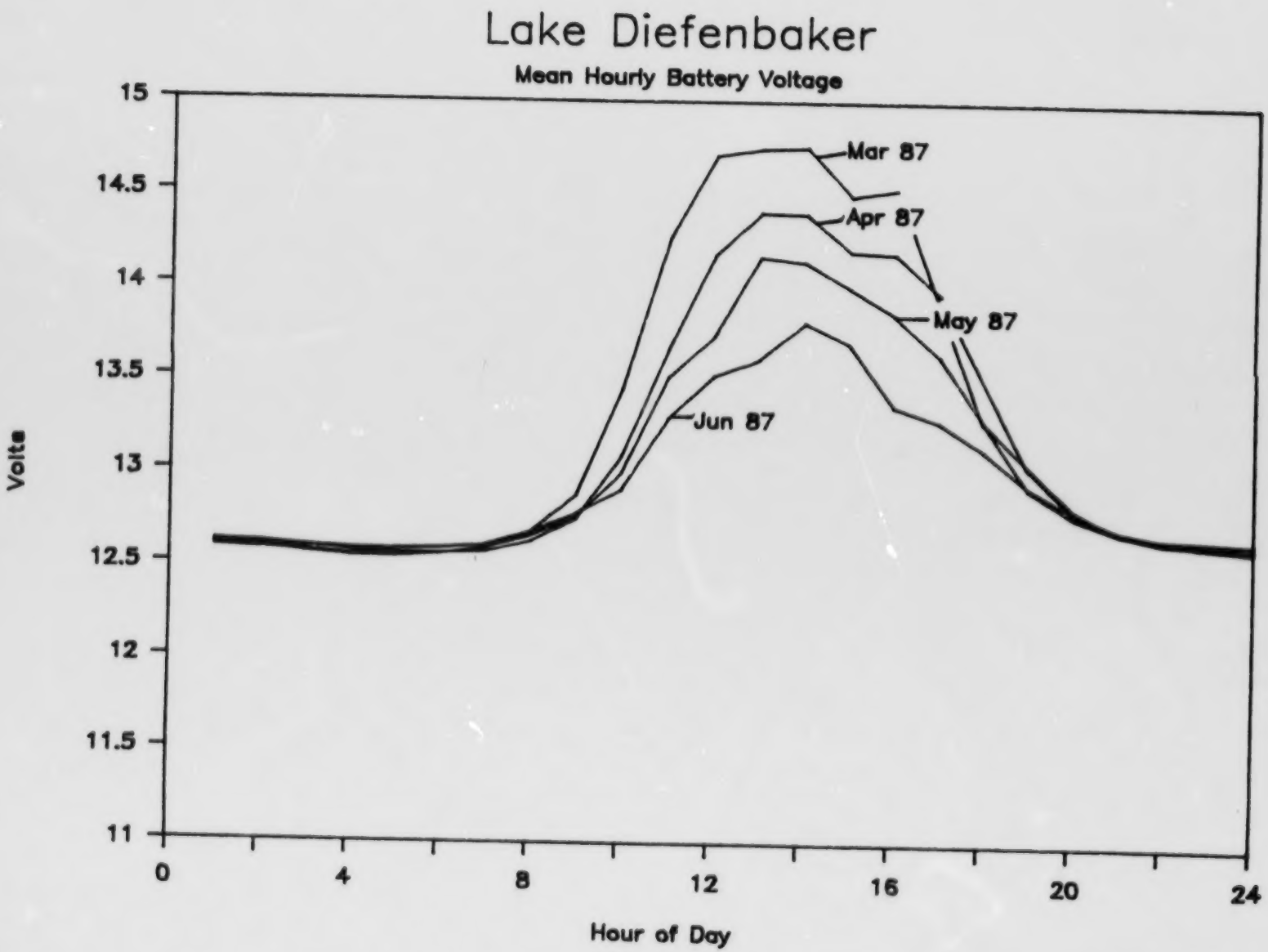
GRAPH 16


Lake Diefenbaker
Mean Hourly Charge Energy
KJ
40
35
30
25
20
15
10
5
0
0
4
8
12
16
20
24
Hour of Day
Feb 87
Apr 87
Jun 87
May 87
Mar 87

GRAPH 17

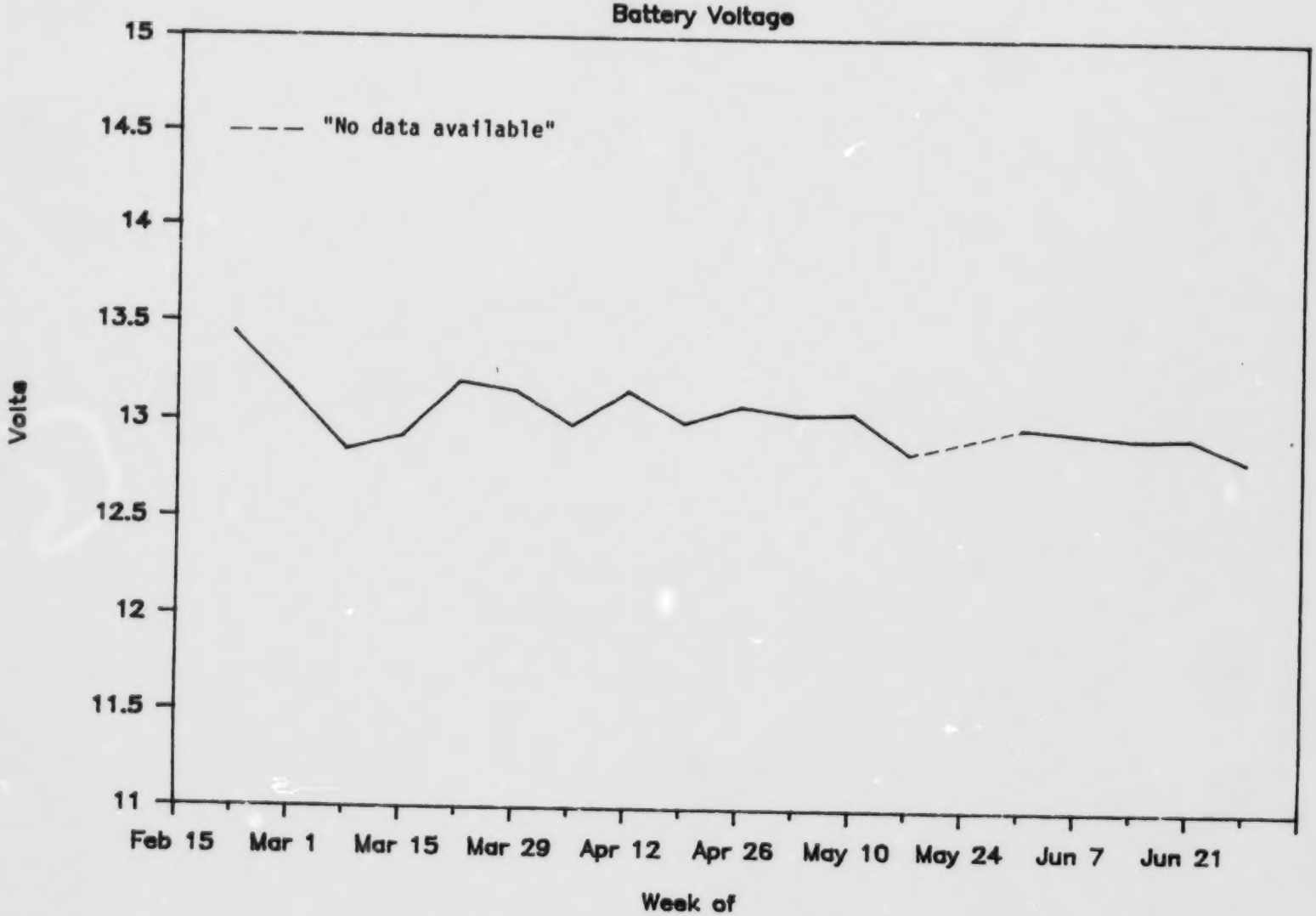

Lake Diefenbaker
Mean Hourly Discharge Energy
KJ
4
3.5
3
2.5
2
1.5
1
0.5
0
0
4
8
12
16
20
24
Hour of Day
Feb 87
Mar 87
Apr 87
May 87
Jun 87

GRAPH 18

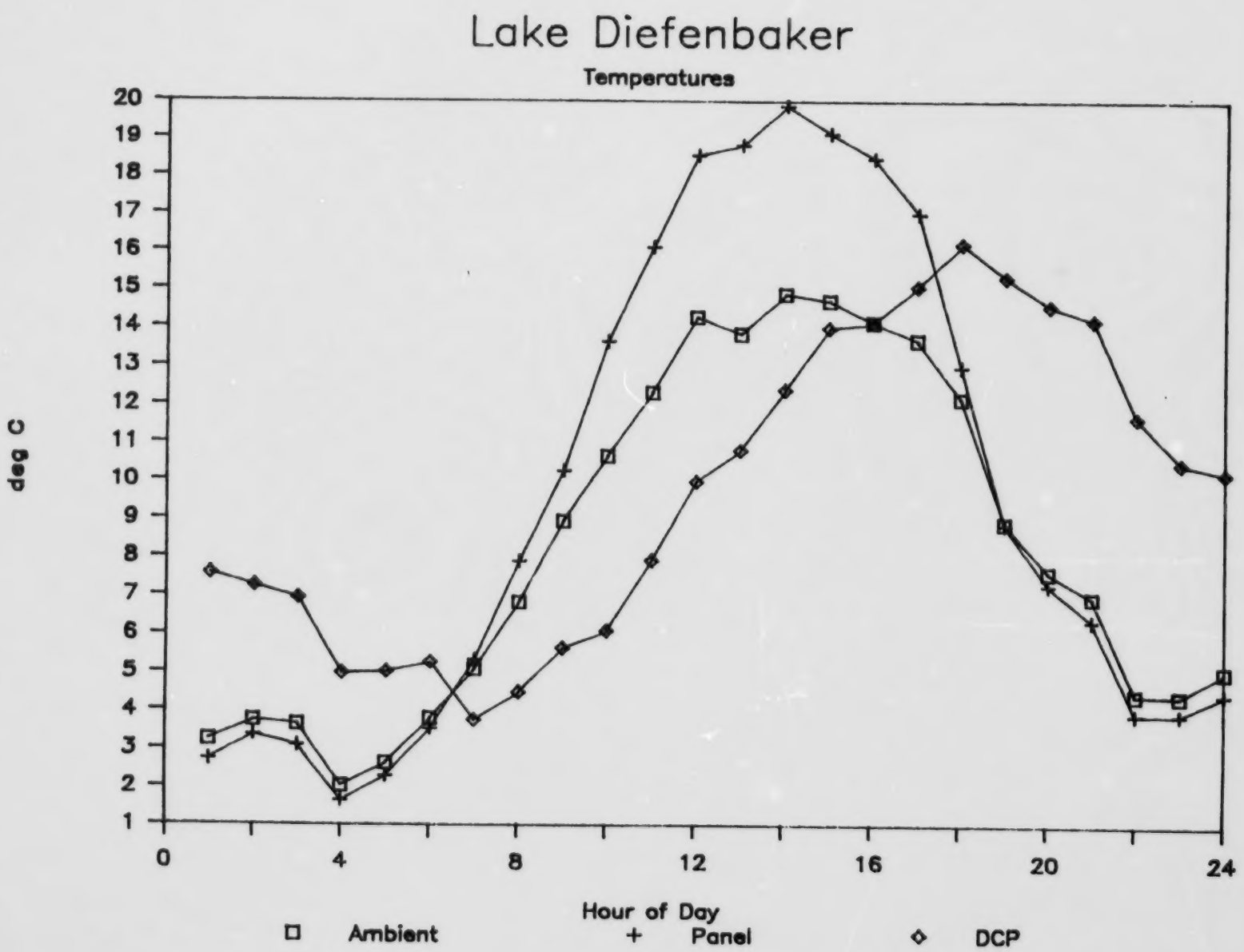

Lake Diefenbaker
Mean Hourly Battery Voltage
15
14.5
14
13.5
13
12.5
12
11.5
11
Volts
Mar 87
Apr 87
May 87
Jun 87
0
4
8
12
16
20
24
Hour of Day

GRAPH 19

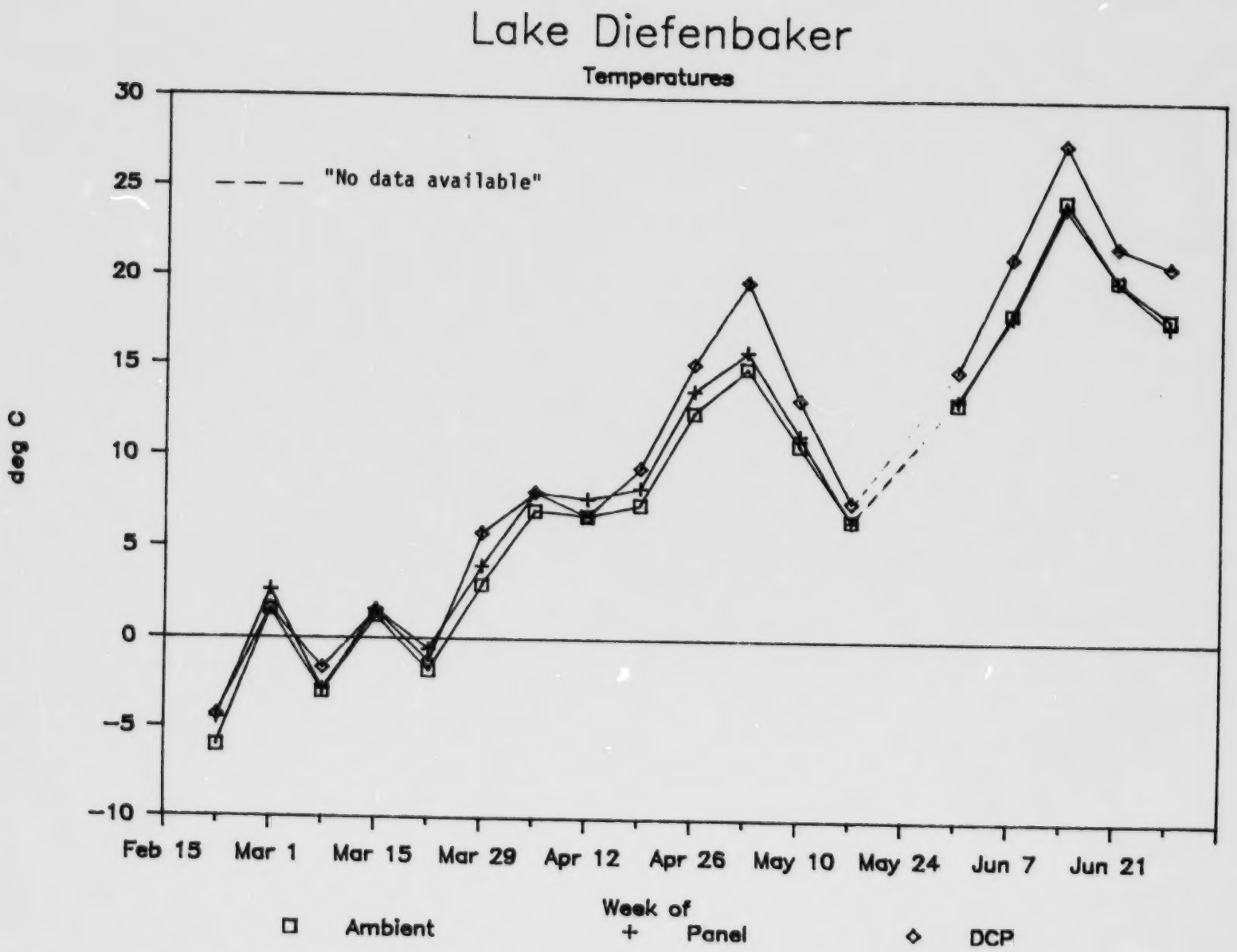
Lake Diefenbaker



GRAPH 20


Lake Diefenbaker
Temperatures
deg C
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
4
8
12
16
20
24
Hour of Day
Ambient
Panel
DCP

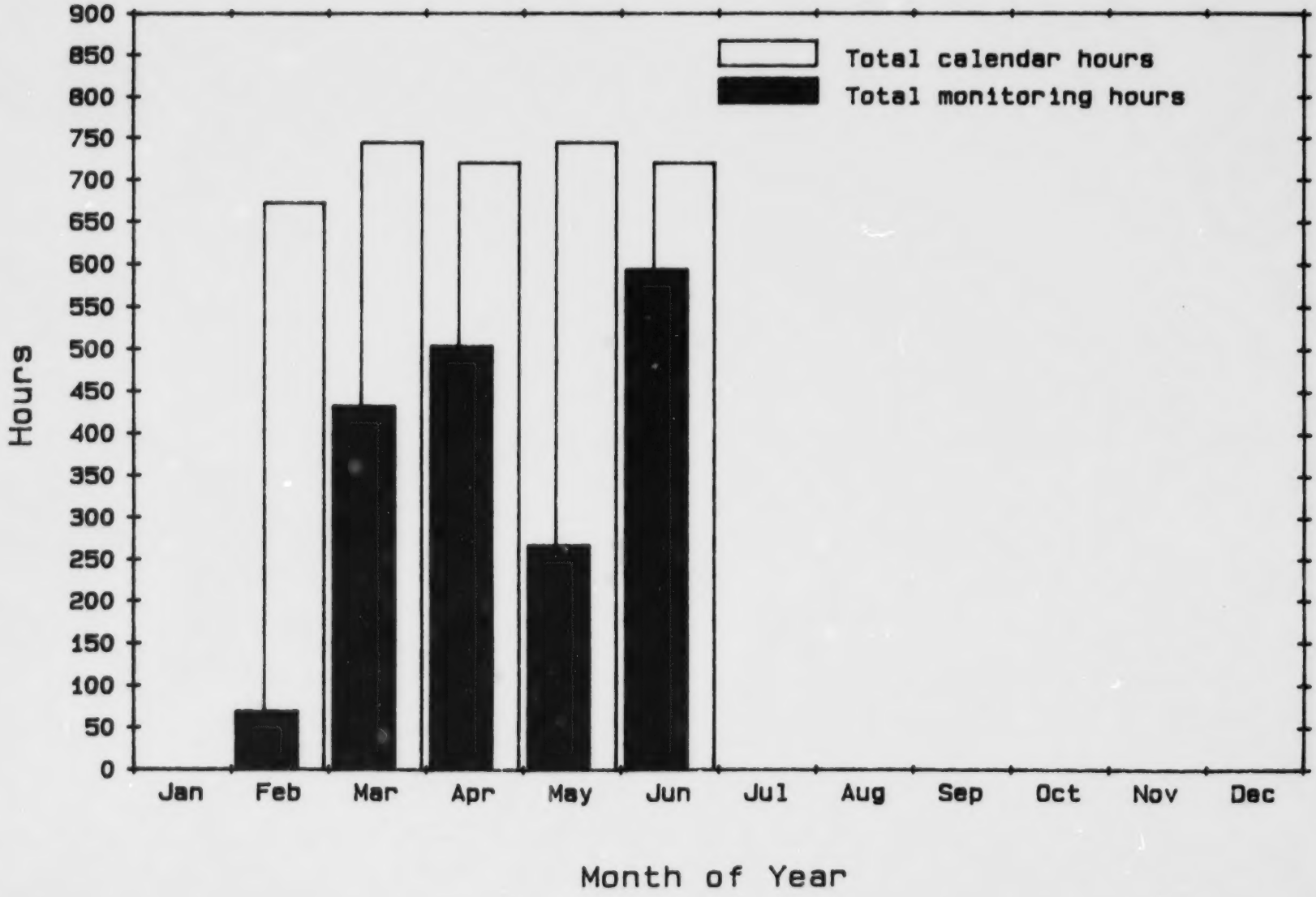
GRAPH 21


Lake Diefenbaker
Temperatures
"No data available"
30
25
20
15
10
5
0
-5
-10
deg C
Feb 15
Mar 1
Mar 15
Mar 29
Apr 12
Apr 26
May 10
May 24
Jun 7
Jun 21
Week of
Ambient
Panel
DCP

GRAPH 22

Calendar Hours vs. Monitoring Hours

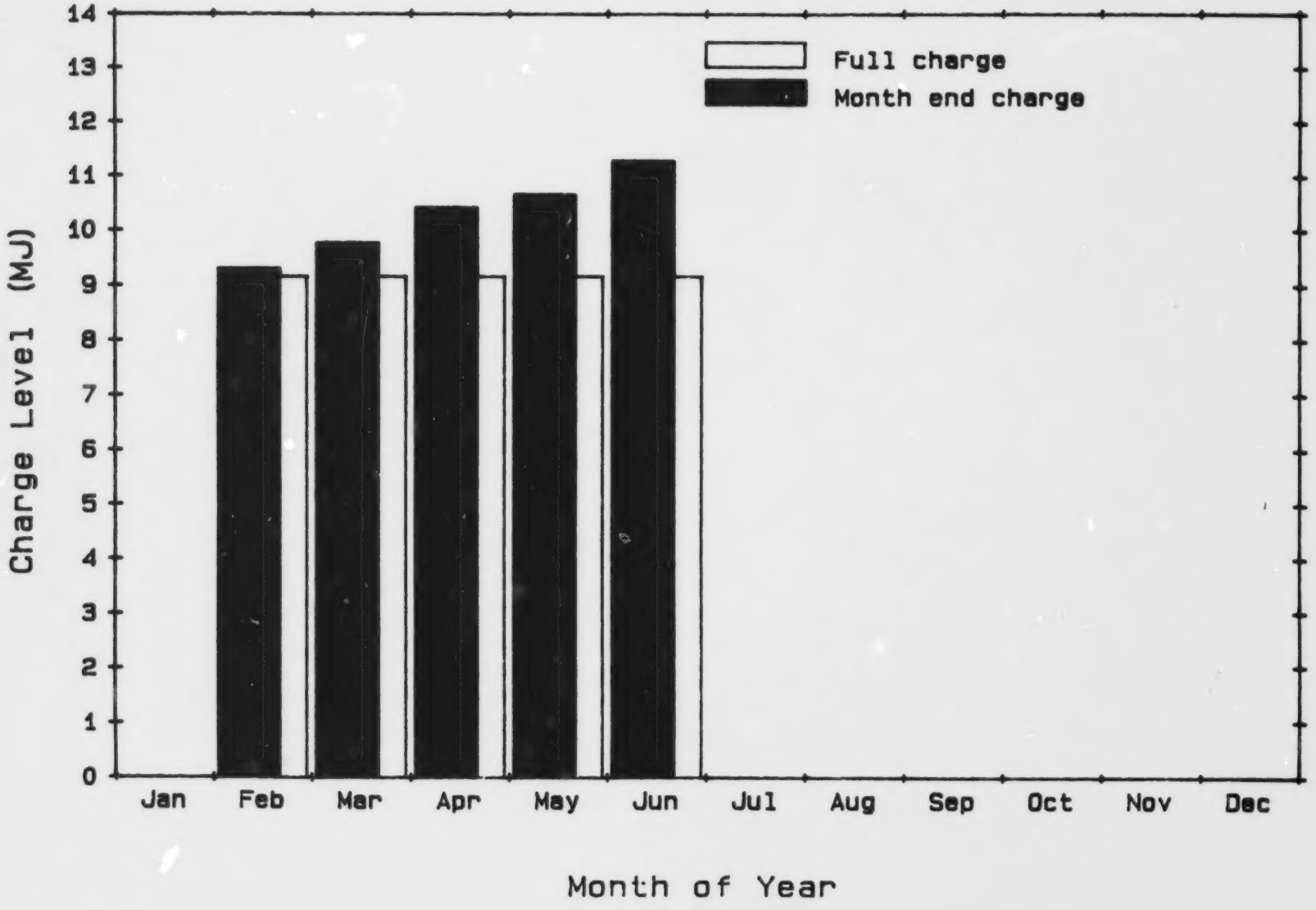
Lake Diefenbaker 1987



GRAPH 23

Battery Charge Level

Lake Diefenbaker, 1987



APPENDIX "C"

Example Tables and Graphs

(June 1987 Data)

Site: Coppermine River, N.W.T.

PV Panel - Manufacturer: Solarex
Model: AH0816000
Type: SX10

Battery - Manufacturer: VARTA
Model: P-125
Type:

Operated by: Environment Canada, Water Resources Branch

Month/Year	Total Avail. Hours	Actual Hours	Mean Daily Horizontal Solar Energy (MJ/m^2)	Mean Daily Vertical Solar Energy (MJ/m^2)	Mean Daily Temperature ($^{\circ}C$)	Battery Charge Level (MJ) * 1
Nov/86	720	653	0.50	1.27	-22.0	8.16
Dec/86	744	363	0.03	0.09	-18.9	7.46
Jan/87	744	346	0.25	0.42	-24.2	6.65
Feb/87	672	353	1.67	6.13	-17.2	6.03
Mar/87	744	398	5.23	12.50	-19.4	* 2
Apr/87	720	156	*3	*3	*3	*3
May/87	744	436	23.73	26.13	-5.6	*2
Jun/87	720	524	20.69	15.47	7.5	*2
Jul/87	744					
Aug/87	744					
Sep/87	720					
Oct/87	744					
Nov/87	720					
Dec/87	744					

Notes: * 1 - Assuming fully charged battery of 9.16 MJ at start of monitoring.

* 2 - Due to sensor failure, charge level unavailable.

* 3 - Insufficient amount of data.

Copperamine River, June, 87
Solar Energy

by Day

	Horizontal Sun (kJ/m^2/hr)				Vertical Sun (kJ/m^2/hr)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	*	*	*	*	*	*	*	*
2	15.51	1821.70	23a.a4	135.37	99.a7	258.30	178.42	39.a2
3	28.15	2a72.30	1259.90	1vaa.50	1a.a8	3392.30	129a.a9	1308.1[illegible]
4	24.19	2320.1v	851.50	64v.aa	a.1[illegible]	2229.a0	58[illegible].8a	5[illegible]
5	a.22	a98.67	335.82	2aa.31	0.00	502.8a	245.9a	18a.9[illegible]
a	11.00	2a2a.50	1145.1v	978.33	7.15	3219.8v	1a8a.[illegible]	1142.[illegible]
7	15.14	2aa5.50	1354.80	1024.4a	8[illegible].78	3140.90	1217.a0	1192.a
8	12.58	4v9.88	2a8.41	127.45	14a.[illegible]	254.[illegible]	194.[illegible]	[illegible]
9	17.87	267a.30	1388.90	911.a1	1aa.81	2937.20	1147.4a	1042.9[illegible]
10	*	*	*	*	*	*	*	*
11	87.19	22aa.70	a40.12	579.67	83.39	18a4.70	422.24	452.28
12	14.99	1a24.10	594.92	524.54	7.54	1252.40	395.45	3a8.[illegible]
13	9.81	497.24	225.53	1a4.83	4.7a	294.a3	145.00	104.5[illegible]
14	5.02	a38.44	324.a9	271.15	3.18	340.30	1a8.25	141.02
15	111.92	2238.70	1079.00	770.91	9a.9[illegible]	224a.30	81a.72	718.a[illegible]
1a	48.90	13a3.60	498.38	418.48	12.71	754.05	28[illegible].aa	227.71
17	29.35	14a7.70	a52.93	470.47	11.91	759.a1	33[illegible].87	219.93
18	13.77	1482.50	715.23	491.17	[illegible].5[illegible]	11a0.70	444.70	33a.19
19	4a.90	21v0.70	8a3.01	a11.79	22.24	1877.40	52a.77	503.35
20	12.54	518.78	223.45	203.98	17.87	323.62	15[illegible].33	131.5[illegible]
21	218.02	21[illegible].30	8a6.67	593.88	18a.22	1391.[illegible]	48a.a9	324.27
22	82.a9	1a78.40	489.43	34a.79	27.4a	629.37	291.29	178.[illegible]
23	93.57	44a.58	2a0.47	148.1v	77.a3	221.57	131.51	a1.29
24	113.54	2a51.6a	127a.50	949.6a	8a.1[illegible]	2835.[illegible]	[illegible]a3.a5	998.4[illegible]
25	1a.93	2aa5.90	1292.70	945.02	2a.a5	28a9.30	978.a4	1015.a[illegible]
2a	[illegible].7a	22a[illegible].4a	824.6a	71a.74	13.5a	18a7.5a	4[illegible]5.52	4[illegible].48
27	28.15	233a.50	9a[illegible].a5	774.97	15.49	2335.4a	[illegible]94.11	[illegible]94.15
28	25.3[illegible]	2794.4a	[illegible]a[illegible].52	832.87	15.88	3923.[illegible]	[illegible]1[illegible].37	1[illegible]5a.1[illegible]
29	22.17	2586.a0	[illegible]9a.37	770.59	11.91	2830.00	73a.a2	812.79
30	9.01	14a2.90	551.41	5a5.57	4.7a	1005.00	324.51	3a8.32

by Hour of Day

	Horizontal Sun (kJ/m^2/day)				Vertical Sun (kJ/m^2 day)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	5.02	23a.77	72.25	a7.33	3.18	222.3a	59.78	a5.58
2	7.41	24a.74	69.69	a2.15	3.57	235.87	57.13	a0.94
3	10.21	218.02	94.39	55.28	4.7a	201.72	77.a3	52.71
4	15.39	242.75	153.80	a7.a0	7.54	189.89	123.89	57.54
5	30.49	512.00	294.57	141.19	16.28	2a9.62	178.89	70.69
a	72.55	759.30	4a7.90	21a.7a	99.27	329.97	238.48	a8.a1
7	52.09	1124.70	682.75	342.77	27.40	423.68	295.4a	104.74
8	174.94	1420.20	914.09	437.95	129.85	588.47	372.05	12a.5a
9	225.a0	1771.30	1124.00	561.90	154.07	887.47	488.55	190.29
10	2a0.42	2108.70	1437.a0	650.11	223.1a	2934.00	970.12	614.82
11	226.52	2794.40	1693.00	767.11	211.64	3923.90	1377.70	920.41
12	4[illegible].90	2592.20	1655.90	7a7.98	253.34	2945.10	141[illegible].90	945.72
13	296.72	2676.30	1643.a0	7aa.19	240.23	3278.30	1495.30	1046.5a
14	2[illegible].13	2a72.30	1645.5a	788.29	210.0a	3392.30	1543.50	1112.50
15	270.39	2572.a0	1755.50	714.63	235.07	3252.90	1a78.40	1082.80
1a	478.09	2366.40	1a00.30	a53.30	294.a3	2866.90	14[illegible].50	862.90
17	497.24	2100.70	1412.a0	554.54	293.84	2226.00	1174.40	667.27
18	2[illegible].57	1807.a0	11a5.20	476.44	212.83	1489.90	825.53	405.86
19	287.80	1427.00	861.36	385.49	185.44	726.a6	470.41	157.02
20	1[illegible]a.0[illegible]	1145.80	700.51	284.56	127.07	492.38	351.25	88.80
21	194.49	9a2.33	537.06	189.74	128.65	430.04	292.00	69.83
22	47.30	565.45	369.78	129.34	19.06	323.62	231.38	70.73
23	18.98	319.34	213.14	79.13	7.94	249.37	162.17	62.37
24	a.22	220.81	123.33	69.55	0.00	216.01	102.77	64.94

* No data available.

Copperaine River, June, 87
System Temperatures

by Da

	DCP temperature (deg C)				Solar Panel Temperature (deg C)				Ambient Air Temperature (deg C)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	*	*	*	*	*	*	*	*	*	*	*	*
2	0.00	0.00	0.00	0.00	-4.39	1.01	-1.24	1.12	-4.79	1.41	-0.99	1.87
3	3.07	8.71	6.30	2.12	-7.19	20.81	7.93	10.78	-5.19	7.21	1.66	3.84
4	2.10	8.83	4.20	1.45	-4.19	11.81	1.33	4.39	-2.79	1.81	-0.09	4.01
5	0.96	0.96	0.96	0.00	-2.19	5.21	0.64	2.07	-1.99	2.81	-0.27	1.68
6	-1.15	13.39	4.29	5.73	-2.39	29.22	10.39	11.78	-2.99	12.21	5.12	5.30
7	8.03	21.03	12.96	4.57	-3.59	37.22	15.16	14.26	-2.39	21.41	10.22	7.57
8	10.69	10.69	10.69	0.00	-1.99	3.21	0.66	2.37	-1.39	3.81	1.51	2.61
9	9.06	19.54	13.09	3.59	-3.79	34.62	14.14	13.15	-2.59	16.21	9.26	6.30
10	*	*	*	*	*	*	*	*	*	*	*	*
11	10.77	18.86	13.19	2.98	6.81	24.61	13.31	5.27	7.01	20.41	12.55	4.19
12	14.07	16.06	15.51	1.46	3.21	29.62	13.66	9.29	3.41	25.41	12.46	6.49
13	2.27	11.96	5.97	3.36	0.61	2.21	1.18	0.48	0.41	1.81	0.84	0.35
14	0.79	1.70	1.11	0.37	0.61	3.01	1.50	0.99	0.61	1.61	1.01	0.36
15	0.28	8.77	4.95	3.77	-0.39	20.81	9.32	5.87	-0.79	8.81	5.57	2.99
16	5.86	7.92	6.70	0.70	3.21	10.61	6.53	2.38	3.01	7.61	5.56	1.29
17	3.75	6.09	4.61	0.72	1.01	9.61	4.59	2.72	0.81	6.41	3.46	1.82
18	2.67	11.96	6.51	3.87	1.21	20.21	10.99	6.38	1.41	16.21	9.59	5.18
19	9.23	18.29	12.74	3.42	2.21	26.82	13.17	7.71	3.01	16.41	11.56	4.79
20	17.09	26.84	21.97	6.89	1.41	18.61	11.38	7.53	2.81	20.81	12.55	7.57
21	19.83	24.84	21.75	1.45	10.21	26.21	17.33	4.75	10.41	23.21	16.76	4.18
22	11.05	17.89	13.25	2.38	1.21	16.21	8.46	4.04	1.41	14.41	7.78	3.35
23	9.06	12.99	11.02	2.78	-0.19	7.41	3.38	3.10	0.01	8.21	4.08	3.46
24	8.88	21.25	13.09	4.58	2.01	32.62	14.89	10.86	2.61	15.01	10.12	4.25
25	13.96	23.82	18.46	3.62	-0.99	36.22	15.98	12.40	0.61	22.81	11.76	6.49
26	15.38	21.08	17.63	1.82	0.61	29.62	11.80	7.84	1.41	20.41	11.85	6.45
27	11.96	19.49	15.82	3.00	0.01	32.42	16.22	9.80	1.01	21.01	14.11	6.24
28	14.70	23.02	18.86	3.05	7.41	260.16	28.45	50.47	-20.57	26.82	15.58	42.36
29	14.76	21.08	17.76	2.55	3.81	38.42	14.77	10.26	4.61	18.21	10.69	4.05
30	11.05	18.40	13.73	3.08	3.61	15.81	8.23	4.11	3.81	10.21	7.09	2.55

by Hour of Day

	DCP temperature (deg C)				Solar Panel Temperature (deg C)				Ambient Air Temperature (deg C)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	*	*	*	*	-7.19	13.61	2.58	4.69	-6.19	14.41	3.06	4.65
2	0.16	24.84	12.67	6.55	-5.59	11.61	2.04	4.31	-4.59	11.41	2.66	4.22
3	*	*	*	*	-5.19	12.41	1.92	4.37	-3.99	12.41	2.51	4.20
4	*	*	*	*	-4.99	13.01	2.01	4.25	-4.19	13.21	2.35	4.21
5	-0.69	22.05	9.96	6.25	-1.39	15.81	5.39	4.37	-1.79	16.81	6.96	5.25
6	*	*	*	*	-0.19	16.81	7.52	5.14	-0.39	19.41	8.94	6.31
7	*	*	*	*	0.81	18.01	8.69	5.37	0.61	22.81	10.16	6.85
8	-1.15	20.86	9.19	5.77	1.01	21.41	9.44	5.49	0.81	23.41	11.07	7.07
9	*	*	*	*	1.81	22.61	11.03	5.41	1.41	26.82	11.68	7.13
10	*	*	*	*	1.81	260.16	25.56	51.58	1.21	21.81	9.91	5.60
11	0.11	21.77	9.59	5.71	1.61	34.22	18.93	9.50	0.01	21.41	10.70	6.52
12	*	*	*	*	1.41	41.42	20.17	11.27	-0.19	25.81	11.14	6.94
13	*	*	*	*	1.01	35.42	20.80	11.36	-2.39	23.21	11.17	6.75
14	0.91	21.88	10.72	5.82	1.01	39.62	20.89	12.54	-2.39	25.41	11.08	6.78
15	*	*	*	*	1.41	39.02	21.13	11.74	-1.59	19.21	11.44	5.96
16	*	*	*	*	1.01	30.02	18.93	9.02	-1.99	21.01	11.47	6.19
17	3.36	21.71	12.84	6.27	-0.19	29.02	17.12	8.50	-1.99	21.61	11.28	6.24
18	*	*	*	*	-1.59	27.02	14.15	7.21	-3.19	22.81	11.36	6.69
19	*	*	*	*	-1.79	17.01	10.53	5.48	-3.39	18.81	10.02	5.98
20	0.96	23.02	13.42	7.08	-2.59	17.81	9.78	5.46	-3.79	20.41	9.56	5.94
21	*	*	*	*	0.41	18.61	8.86	5.20	-0.39	20.81	9.42	5.76
22	*	*	*	*	-1.19	17.21	7.02	5.04	-1.39	18.81	8.08	5.59
23	0.96	26.84	14.50	7.10	-4.59	14.01	4.48	4.67	-3.99	14.21	4.76	4.70
24	*	*	*	*	-4.99	14.61	3.55	4.65	-4.39	14.81	3.96	4.65

* No data available.

Coppermine River, June, 87
System Voltages

By Day

	Battery (volts)				PV Panel (volts)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	*	*	*	*	*	*	*	*
2	12.69	12.69	12.69	0.00	13.22	13.68	13.44	0.24
3	12.64	13.14	12.84	0.20	12.71	14.76	13.91	0.87
4	12.65	12.91	12.73	0.09	12.72	14.42	13.70	0.81
5	12.59	12.68	12.63	0.05	12.62	13.73	13.43	0.40
6	12.57	13.14	12.79	0.20	12.63	14.77	13.81	0.84
7	12.64	13.11	12.81	0.19	12.78	14.94	13.94	0.88
8	12.70	12.70	12.70	0.00	13.25	13.79	13.51	0.23
9	12.66	13.05	12.81	0.15	12.76	14.79	13.96	0.80
10	*	*	*	*	*	*	*	*
11	12.62	12.80	12.69	0.06	12.71	14.22	13.49	0.45
12	12.62	12.92	12.70	0.12	12.65	14.15	13.46	0.48
13	12.55	12.61	12.59	0.02	12.61	13.66	13.23	0.42
14	12.55	12.58	12.56	0.01	12.61	13.61	13.19	0.46
15	12.55	12.91	12.71	0.14	12.67	14.40	13.78	0.47
16	12.55	12.68	12.60	0.05	12.62	13.86	13.37	0.43
17	12.54	12.64	12.58	0.04	12.58	13.86	13.44	0.43
18	12.52	12.70	12.61	0.07	12.59	14.00	13.55	0.41
19	12.55	12.78	12.63	0.08	12.60	14.27	13.80	0.49
20	12.56	12.64	12.60	0.06	12.60	13.63	13.04	0.48
21	12.59	12.73	12.64	0.05	12.76	14.26	13.52	0.47
22	12.55	12.62	12.58	0.02	12.66	13.73	13.36	0.38
23	12.54	12.64	12.59	0.07	12.63	13.59	13.07	0.45
24	12.59	13.05	12.75	0.17	12.70	14.72	13.81	0.61
25	12.60	13.05	12.76	0.16	12.66	14.87	13.88	0.63
26	12.63	12.68	12.64	0.06	12.66	14.42	13.62	0.48
27	12.61	12.91	12.73	0.12	12.66	14.59	13.74	0.55
28	12.61	12.80	12.71	0.09	12.64	14.57	13.69	0.58
29	12.62	13.01	12.73	0.14	12.65	14.74	13.71	0.62
30	12.61	12.71	12.64	0.04	12.65	14.02	13.37	0.51

By Hour of Day

	Battery (volts)				PV Panel (volts)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	*	*	*	*	12.59	12.81	12.69	0.07
2	12.52	12.66	12.60	0.04	12.59	12.78	12.68	0.06
3	*	*	*	*	12.61	13.29	12.86	0.25
4	*	*	*	*	12.62	13.55	13.21	0.34
5	12.53	12.66	12.60	0.04	12.62	13.60	13.36	0.32
6	*	*	*	*	13.00	13.71	13.50	0.16
7	*	*	*	*	12.66	13.75	13.57	0.22
8	12.55	12.69	12.62	0.04	13.21	13.85	13.65	0.14
9	*	*	*	*	13.38	13.91	13.72	0.14
10	*	*	*	*	13.51	14.16	13.88	0.21
11	12.58	13.01	12.77	0.14	13.51	14.49	14.06	0.34
12	*	*	*	*	13.56	14.70	14.12	0.40
13	*	*	*	*	13.57	14.79	14.17	0.44
14	12.57	13.14	12.84	0.19	13.54	14.94	14.20	0.46
15	*	*	*	*	13.55	14.82	14.26	0.45
16	*	*	*	*	13.66	14.71	14.19	0.39
17	12.59	12.95	12.79	0.12	13.63	14.55	14.09	0.30
18	*	*	*	*	13.53	14.26	13.93	0.21
19	*	*	*	*	13.50	14.09	13.79	0.16
20	12.57	12.79	12.68	0.07	13.40	13.90	13.70	0.13
21	*	*	*	*	13.29	13.85	13.63	0.12
22	*	*	*	*	12.62	13.73	13.50	0.28
23	12.54	12.71	12.63	0.05	12.62	13.58	13.34	0.30
24	*	*	*	*	12.58	13.33	12.96	0.26

* No data available.

Copperamine River, June, 87
System Currents

By Day

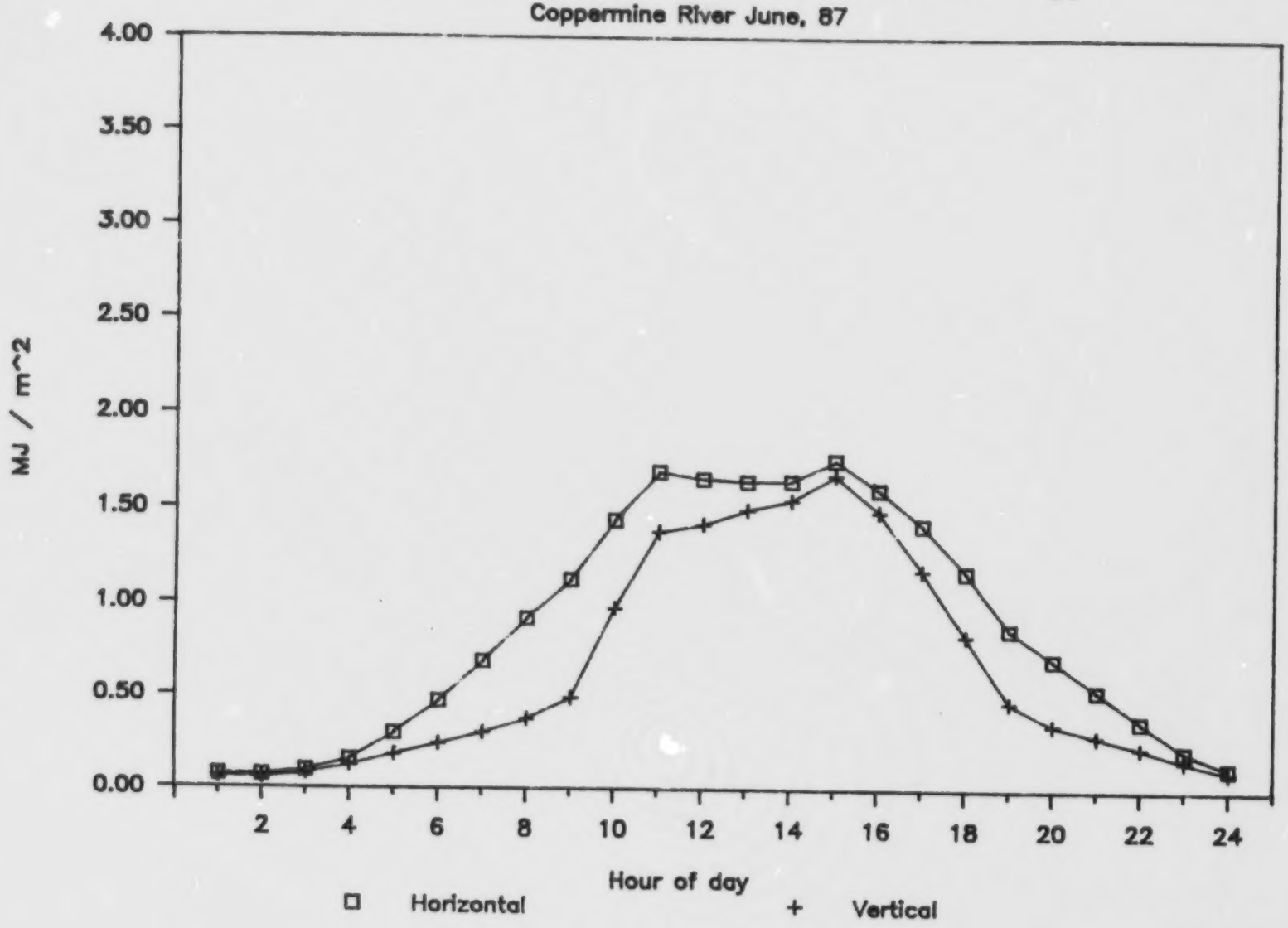
	Charge (mA)				Discharge (mA)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	*	*	*	*	*	*	*	*
2	1.92	4.23	3.39	1.25	71.02	75.94	73.60	2.47
3	-0.13	5.44	3.71	1.80	31.16	169.59	102.85	45.76
4	-0.18	5.32	3.79	1.54	31.38	134.13	85.21	35.54
5	0.90	4.59	3.36	1.72	35.23	79.71	62.62	16.39
6	-0.89	5.40	3.66	1.77	30.95	168.78	96.31	40.25
7	0.20	5.53	3.89	1.64	67.91	189.13	119.99	42.95
8	1.64	4.08	3.24	1.58	86.04	95.83	91.11	4.35
9	0.51	5.55	4.08	1.47	67.64	185.14	121.59	37.54
10	*	*	*	*	*	*	*	*
11	-0.26	4.92	3.09	1.86	70.23	153.81	94.31	18.59
12	-1.00	4.91	3.02	1.89	44.64	145.46	98.31	24.87
13	-1.05	4.42	2.49	2.03	30.95	88.37	61.92	19.96
14	-0.13	4.55	2.86	2.12	30.73	85.40	58.08	20.05
15	-0.29	5.29	4.10	1.20	59.98	150.43	95.64	25.47
16	-0.94	4.78	3.11	1.82	34.82	108.16	74.35	18.96
17	-1.00	4.80	3.40	1.80	44.22	101.35	79.02	15.45
18	-0.44	5.34	3.69	1.65	31.16	118.61	81.71	22.69
19	-0.13	5.24	3.68	1.41	31.59	142.60	93.36	26.81
20	-0.29	4.05	1.45	2.19	32.23	121.79	80.07	44.86
21	0.33	5.17	3.29	1.61	91.63	175.23	135.26	17.98
22	0.10	4.77	3.01	1.68	34.73	117.54	86.60	18.51
23	-0.12	4.15	1.68	2.04	61.97	88.51	72.33	11.12
24	-0.20	5.31	3.69	1.59	59.13	181.01	117.15	35.31
25	-0.34	5.30	3.78	1.52	32.23	207.03	127.77	46.72
26	-0.40	5.56	3.45	1.80	32.45	168.78	104.12	34.61
27	-0.29	5.24	3.50	1.68	32.02	162.50	108.95	37.85
28	-1.05	369.50	25.81	81.32	32.23	190.62	118.54	45.87
29	-1.11	5.49	3.41	2.06	32.23	187.57	112.03	42.98
30	-1.16	4.69	2.62	2.19	32.45	112.09	75.24	28.29

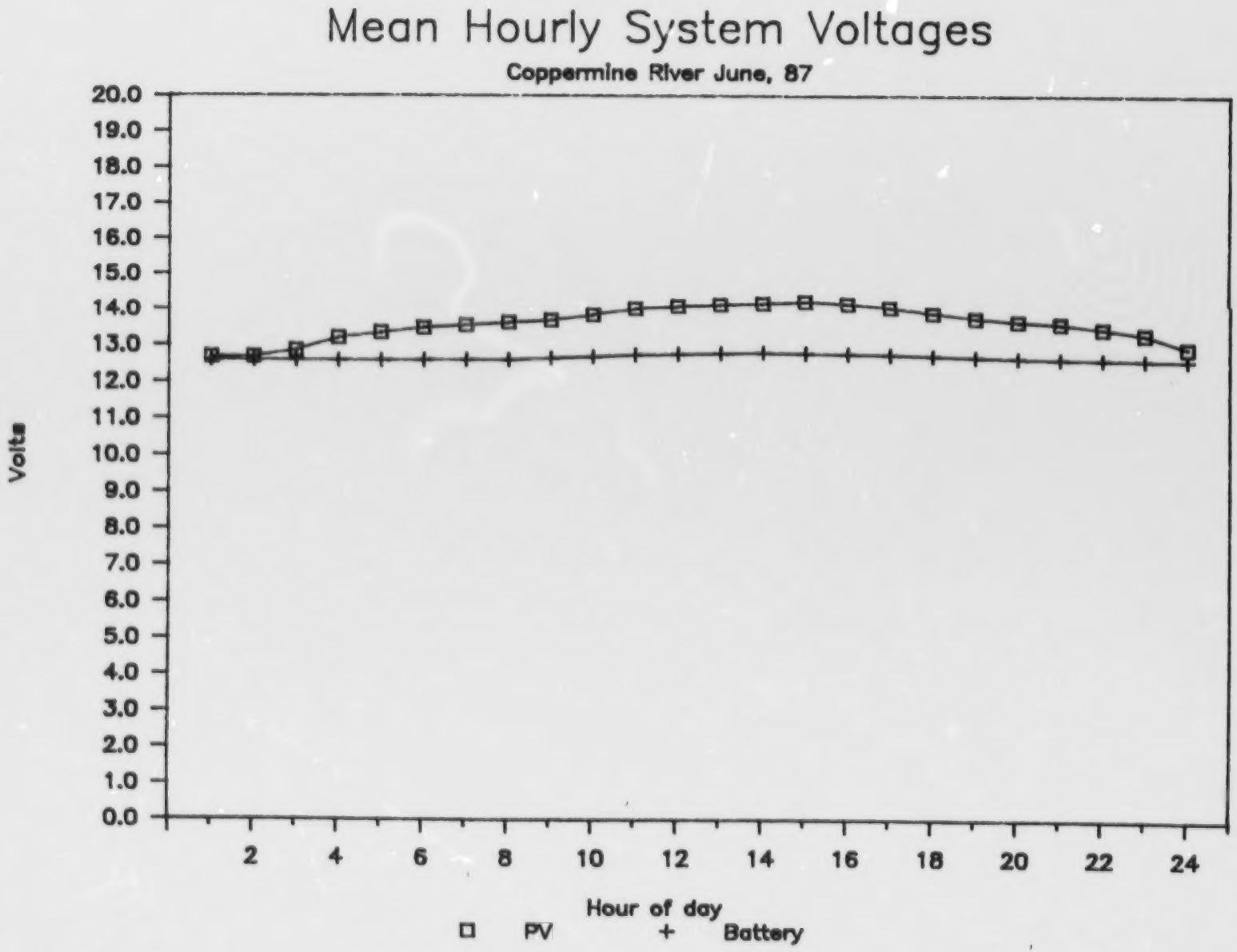
By Hour of Day

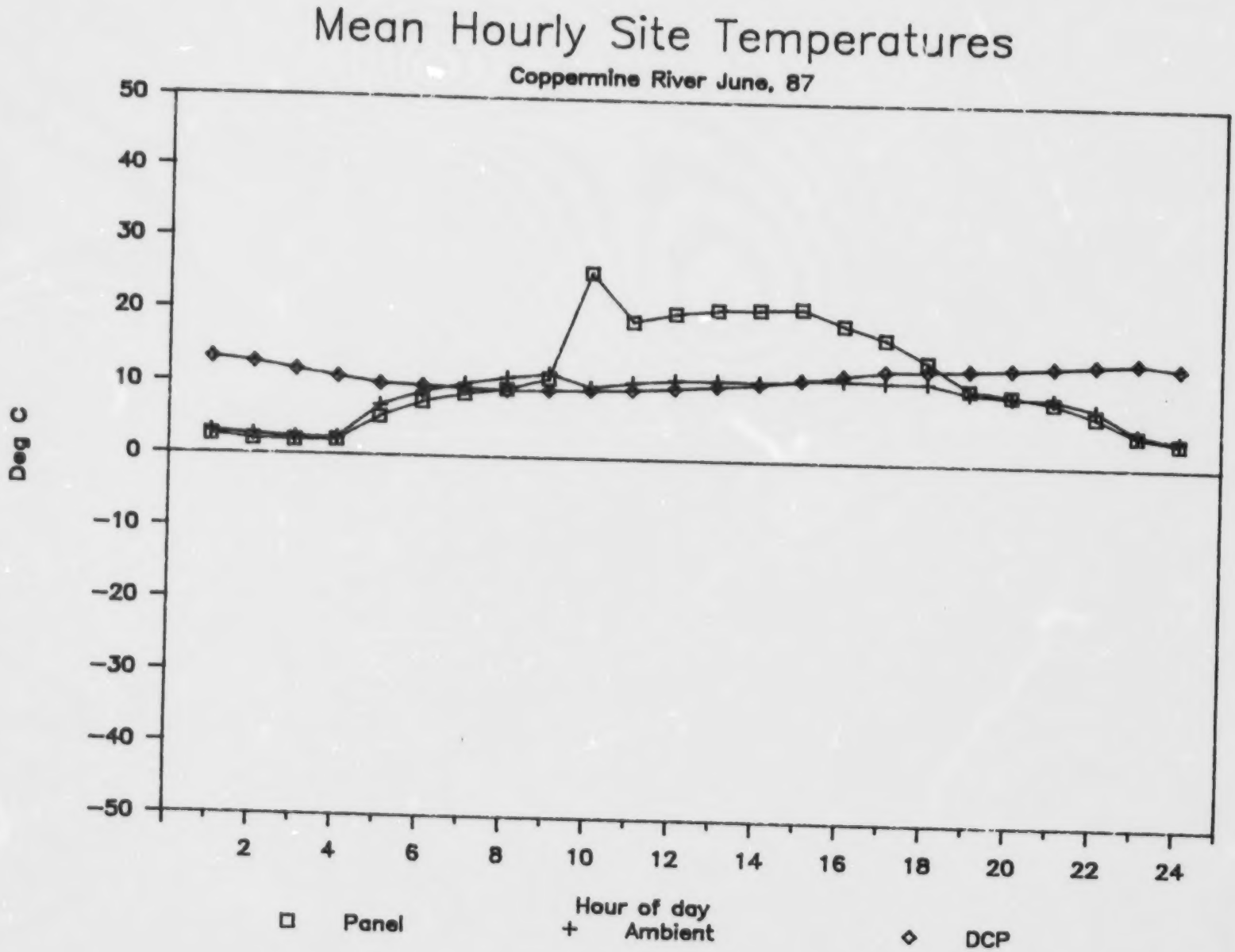
	Charge (mA)				Discharge (mA)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	-0.45	0.78	0.02	0.35	31.16	139.98	55.85	33.93
2	-0.40	0.78	0.06	0.33	30.95	149.55	54.46	31.91
3	-1.16	2.75	0.26	1.14	39.94	133.48	70.62	24.11
4	-0.34	4.17	2.63	1.64	31.16	96.24	65.98	19.75
5	-0.08	4.48	3.31	1.48	30.73	117.62	72.00	19.06
6	0.74	4.07	3.24	0.69	63.80	126.95	91.30	13.75
7	0.19	4.63	4.08	0.92	34.73	116.89	81.19	16.82
8	2.52	4.78	4.35	0.46	54.39	136.89	87.30	17.35
9	3.09	4.30	3.82	0.29	76.42	153.66	105.36	17.67
10	4.06	369.50	20.60	78.06	65.95	156.58	106.02	23.30
11	4.23	176.73	12.37	35.83	66.75	175.23	120.26	32.26
12	3.50	5.01	4.29	0.42	84.79	189.34	133.13	33.87
13	4.21	5.55	4.89	0.39	70.71	185.40	123.77	36.56
14	4.16	5.49	4.91	0.41	69.17	192.65	127.60	37.52
15	3.49	4.96	4.27	0.39	82.71	207.03	145.44	38.61
16	4.42	5.34	4.87	0.31	79.47	190.51	130.82	37.29
17	4.21	5.09	4.67	0.26	74.95	182.18	124.39	31.87
18	3.40	4.26	3.91	0.24	86.27	187.87	125.85	28.79
19	3.72	4.66	4.34	0.26	62.98	145.94	102.30	23.37
20	3.75	4.69	4.29	0.27	58.01	131.91	95.27	21.03
21	2.34	3.84	3.45	0.35	77.27	143.32	104.40	21.31
22	-0.07	4.44	3.67	1.11	30.95	147.49	89.25	26.23
23	-0.18	4.19	3.03	1.37	31.38	139.14	79.01	24.69
24	-1.11	2.57	0.65	1.15	35.23	150.46	80.26	29.12

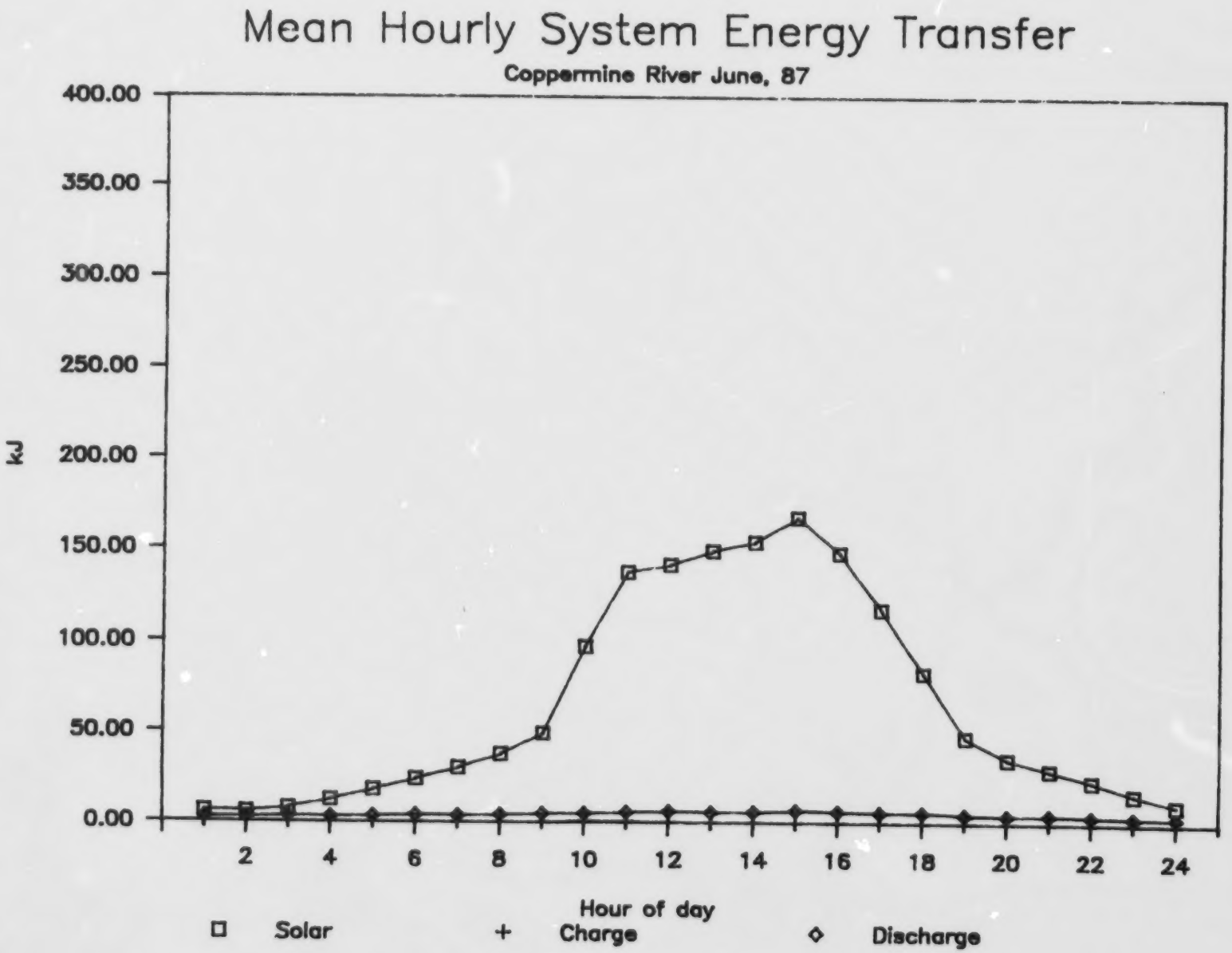
* No data available.

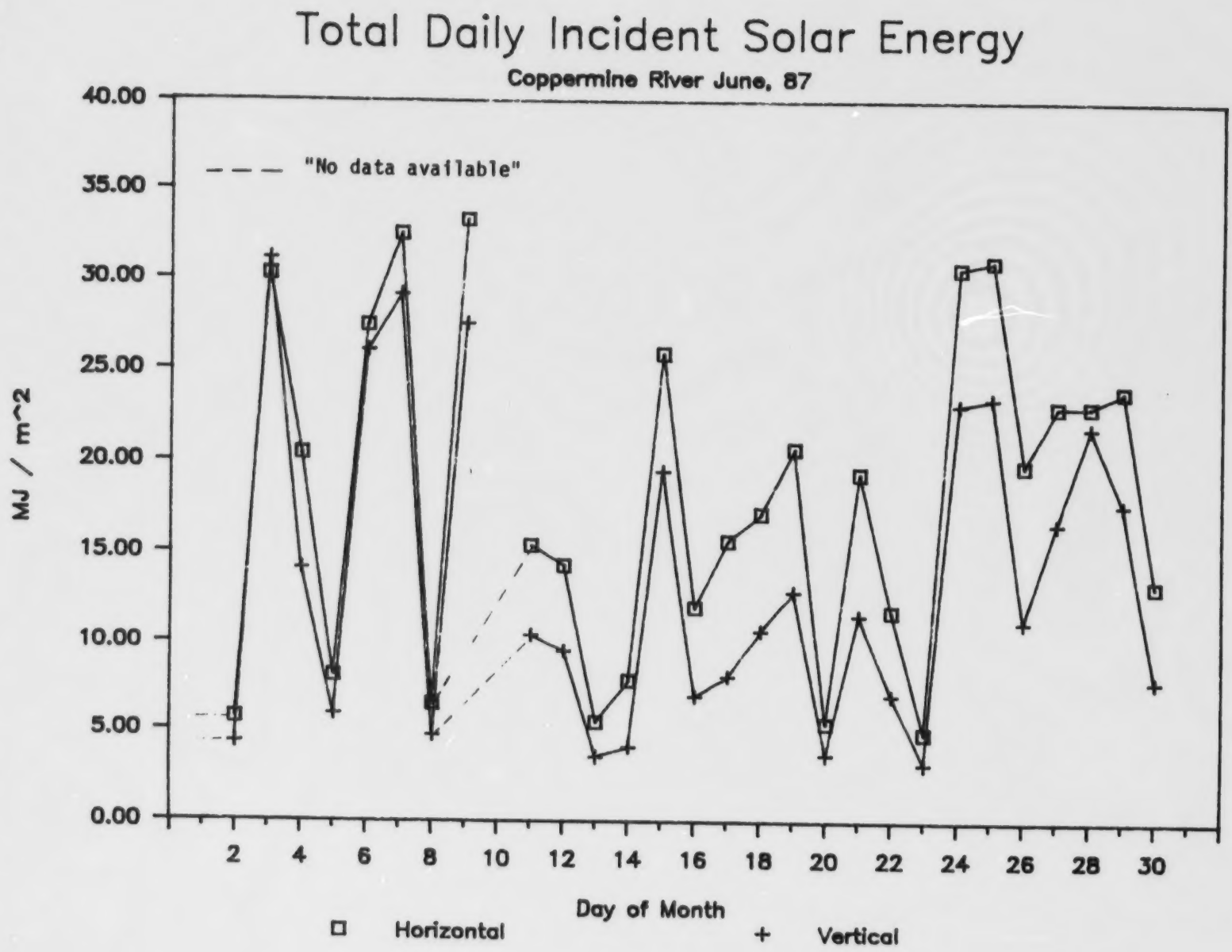
Mean Hourly Incident Solar Energy

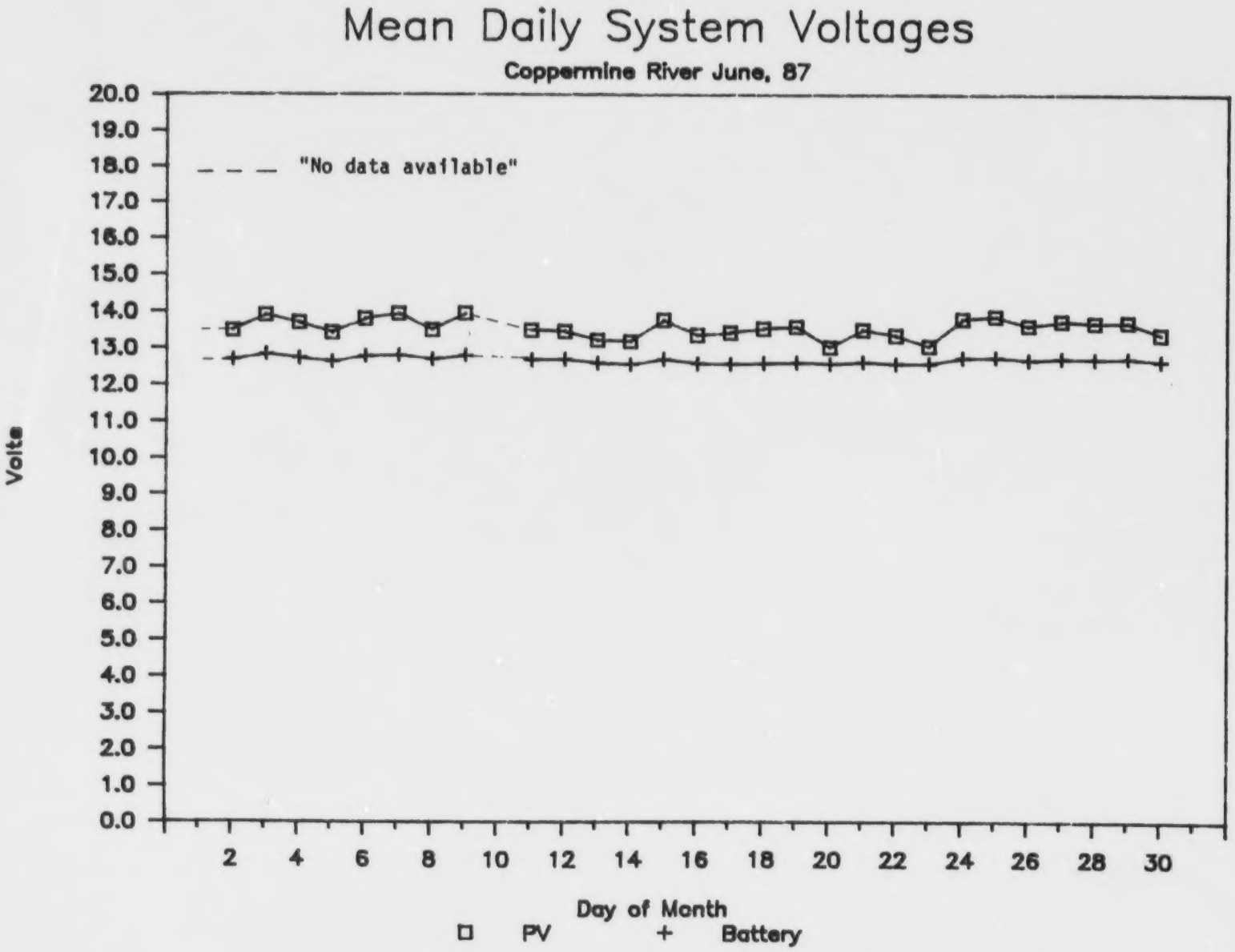


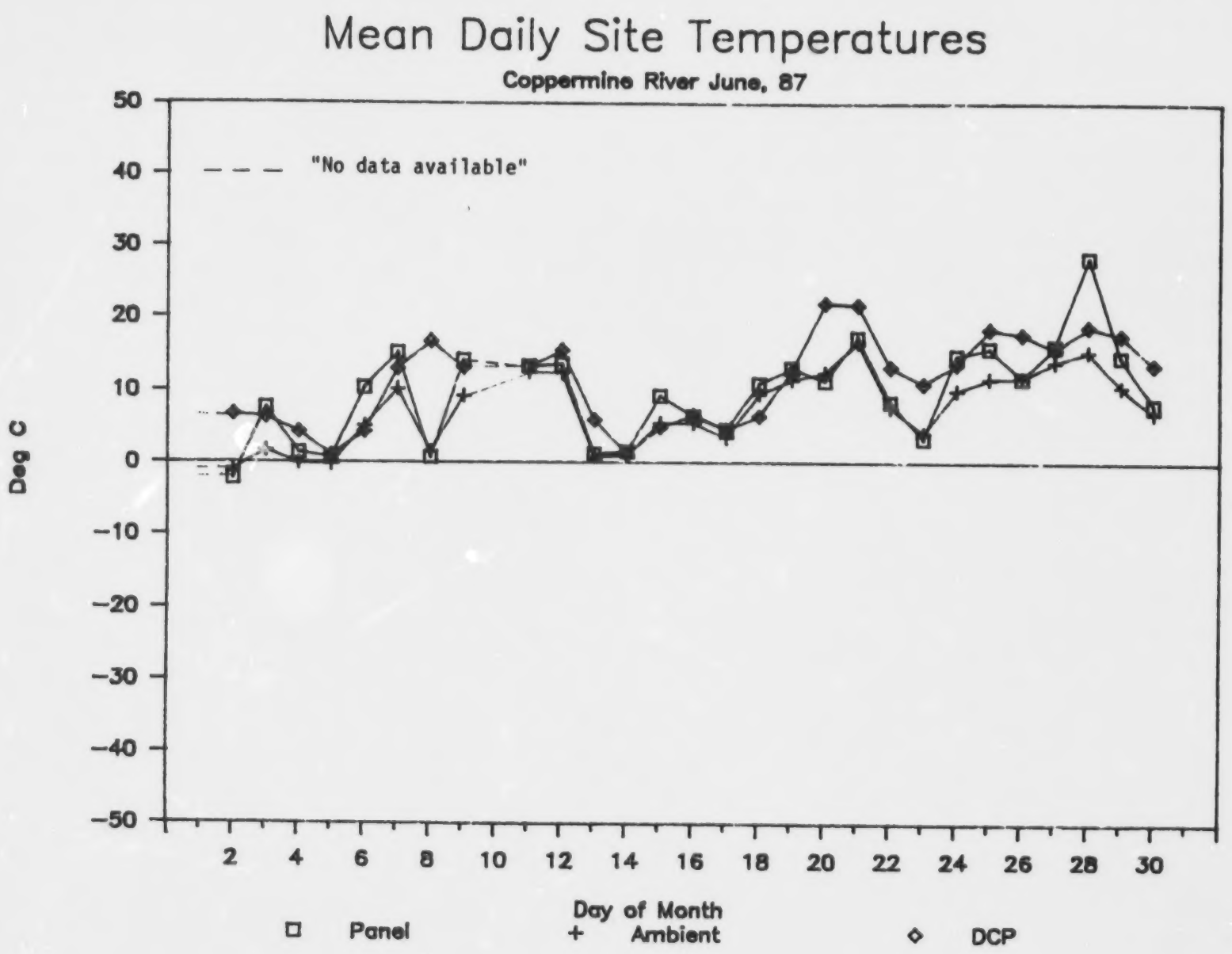

Mean Hourly System Voltages
Coppermine River June, 87
Volts
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2
4
6
8
10
12
14
16
18
20
22
24
Hour of day
PV
Battery

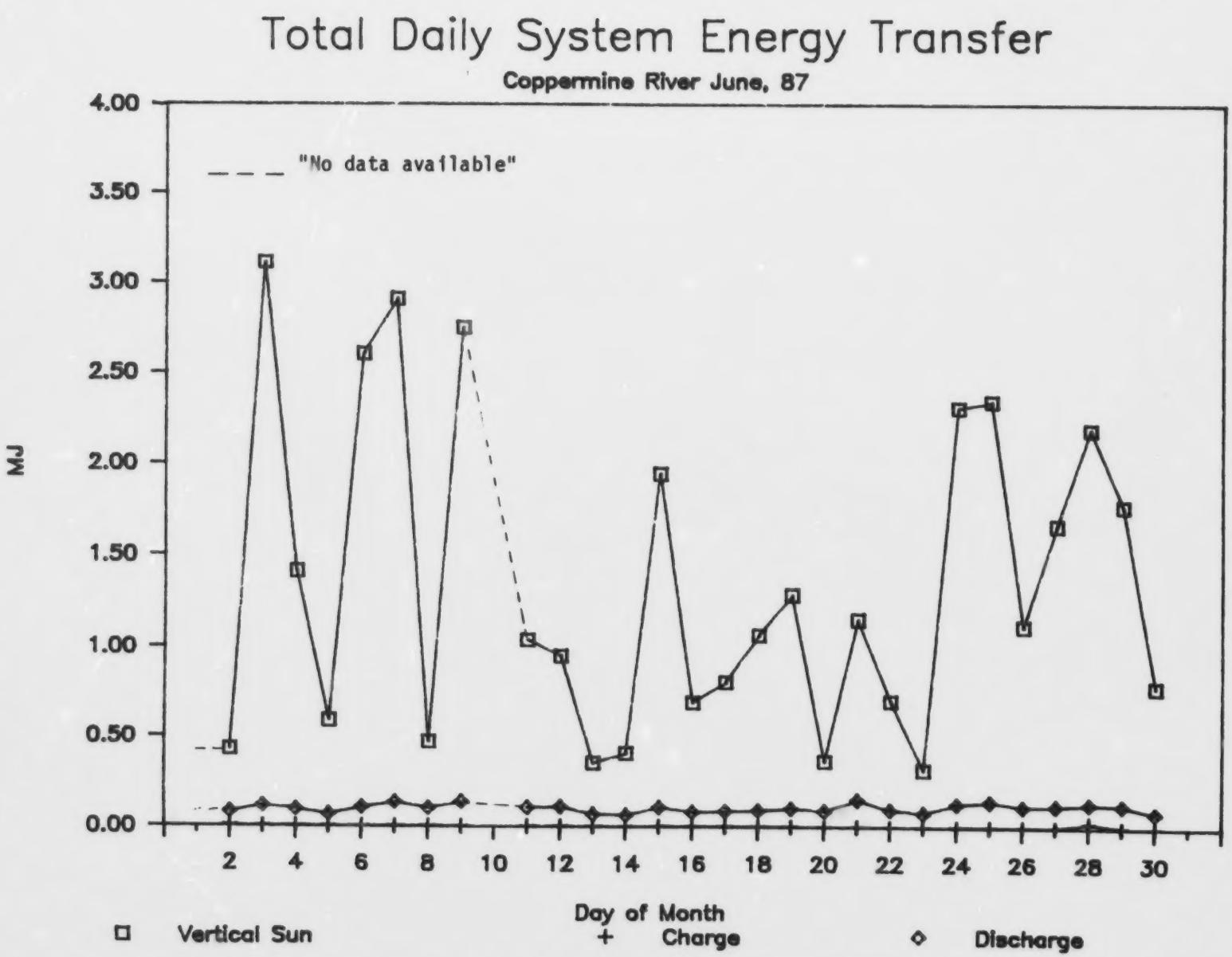

Mean Hourly Site Temperatures
Coppermine River June, 87
Deg C
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
4
6
8
10
12
14
16
18
20
22
24
Hour of day
Panel
Ambient
DCP


Mean Hourly System Energy Transfer
Coppermine River June, 87
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
kW
2
4
6
8
10
12
14
16
18
20
22
24
Hour of day
Solar
Charge
Discharge

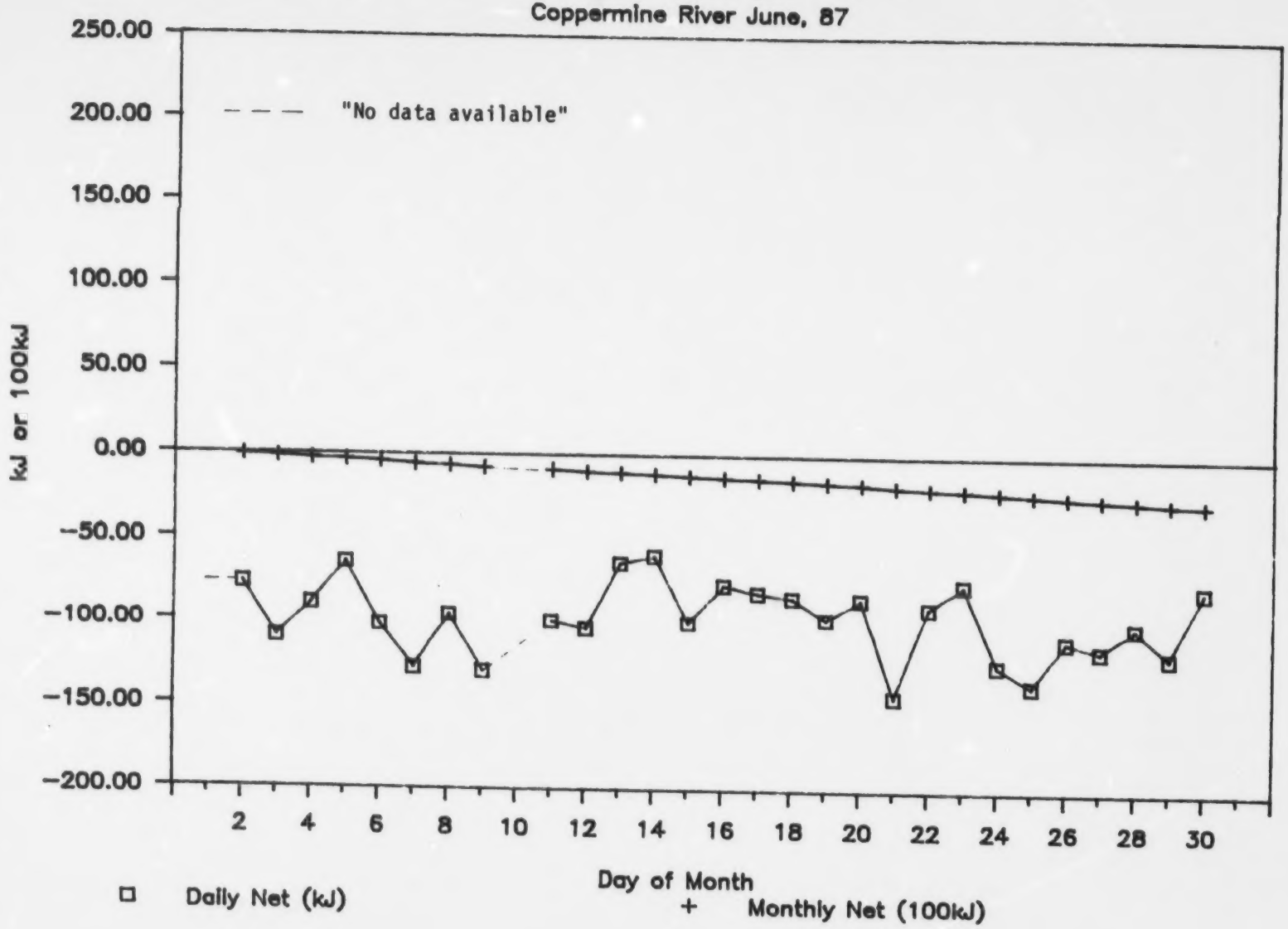

Total Daily Incident Solar Energy
Coppermine River June, 87
"No data available"
MJ / m^2
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Day of Month
Horizontal
Vertical


Mean Daily System Voltages
Coppermine River June, 87
"No data available"
Volts
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Day of Month
PV
Battery


Mean Daily Site Temperatures
Coppermine River June, 87
"No data available"
Deg C
50
40
30
20
10
0
-10
-20
-30
-40
-50
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Day of Month
Panel
Ambient
DCP


Total Daily System Energy Transfer
Coppermine River June, 87
"No data available"
MJ
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Day of Month
Vertical Sun
Charge
Discharge

Battery Charge Level



Site: Lake Diefenbaker, Saskatchewan

PV Panel - Manufacturer: Solarex
Model: AH0811000
Type: SX10

Battery - Manufacturer: VARTA
Model: P-125
Type:

Operated by: Environment Canada, Water Resources Branch

Month/Year	Total Avail. Hours	Actual Hours	Mean Daily Horizontal Solar Energy (MJ/m^2)	Mean Daily Vertical Solar Energy (MJ/m^2)	Mean Daily Temperature (^oC)	Battery Charge Level (MJ) *1 *2
Nov/86	720	-	-	-	-	-
Dec/86	744	-	-	-	-	-
Jan/87	744	-	-	-	-	-
Feb/87	672	69	11.89	27.98	- 1.1	-
Mar/87	744	432	11.01	14.28	0.5	9.77
Apr/87	720	503	17.54	15.13	9.1	10.41
May/87	744	266	20.80	13.69	16.1	10.65
Jun/87	720	594	22.61	11.96	20.7	11.28
Jul/87	744					
Aug/87	744					
Sep/87	720					
Oct/87	744					
Nov/87	720					
Dec/87	744					

*1 Assuming fully charged batteries of 9.16 MJ at start of monitoring.

*2 Adjusted to account for energy consumed by manometer.

Lake Diefenbaker, June, 87
Solar Energy

by Day

	Horizontal Sun (kJ/m^2/hr)				Vertical Sun (kJ/m^2/hr)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	*	*	*	*	*	*	*	*
2	8.71	361.55	93.85	152.71	6.15	233.92	63.89	96.22
3	8.71	3057.10	1024.80	1097.90	6.15	1853.00	505.58	605.54
4	8.71	3132.80	1066.50	1153.50	6.56	2204.60	651.07	785.85
5	8.71	3238.90	934.21	1126.50	6.56	2049.60	485.22	633.49
6	9.11	3186.60	1096.80	1180.80	6.97	2232.30	658.29	792.93
7	9.11	3227.40	1190.00	1270.20	6.97	2210.70	636.38	795.36
8	*	*	*	*	*	*	*	*
9	9.11	2950.20	1187.30	1120.20	7.37	1867.30	563.42	596.13
10	9.11	2540.30	730.90	786.32	6.97	1682.90	469.69	537.69
11	9.11	3213.10	1220.70	1246.20	6.56	2103.10	649.10	784.89
12	9.11	2982.70	1123.20	1053.70	6.97	1709.70	594.02	586.61
13	9.11	9.50	9.31	0.28	7.78	8.18	7.98	0.29
14	9.11	3220.30	1194.40	1286.00	6.97	2137.20	610.84	774.64
15	9.11	3185.40	1231.20	1223.10	7.78	2209.50	693.76	771.16
16	9.11	2442.90	554.06	750.74	7.78	1523.40	361.24	501.32
17	9.11	3227.40	1175.70	1262.50	6.97	2160.40	593.47	742.22
18	9.11	3244.80	1199.70	1272.30	6.97	2147.40	626.78	776.85
19	9.11	2371.60	695.26	806.85	6.97	1609.00	410.24	502.39
20	9.11	2730.40	775.37	927.78	6.56	1575.30	344.25	429.66
21	9.11	3231.00	1388.60	1276.50	6.56	2166.10	714.43	801.00
22	9.11	2094.80	756.97	637.62	7.37	1462.90	457.73	435.46
23	9.11	3198.50	771.82	1017.00	6.56	1460.00	340.97	425.57
24	8.71	2084.90	690.16	716.47	6.56	1168.10	365.50	371.57
25	8.71	3287.60	1177.60	1281.30	6.15	2179.50	603.04	777.74
26	9.11	3176.70	1141.70	1248.20	6.56	2149.80	578.55	741.36
27	9.11	3180.30	940.86	1119.80	6.97	1680.90	426.16	554.03
28	8.71	2409.30	557.55	737.44	6.56	1261.50	275.20	357.88
29	8.71	3335.50	1085.80	1175.50	6.15	2108.00	607.19	709.28
30	9.11	912.78	335.83	298.04	6.97	468.59	168.02	148.77

by Hour of Day

	Horizontal Sun (kJ/m^2/day)				Vertical Sun (kJ/m^2/day)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	9.11	9.50	9.31	0.20	6.97	8.59	7.87	0.47
2	8.71	9.50	9.07	0.20	6.15	7.78	6.93	0.44
3	8.71	9.11	9.07	0.11	6.15	7.78	6.86	0.41
4	9.11	9.50	9.28	0.20	6.56	8.18	7.55	0.42
5	22.67	31.68	23.46	5.16	9.00	23.21	17.21	4.16
6	50.69	218.59	147.63	35.51	37.01	119.92	80.19	16.48
7	174.24	427.28	292.91	67.99	105.22	215.65	153.04	27.27
8	320.36	1041.90	804.78	202.96	161.65	346.79	245.52	52.17
9	416.20	1909.50	1389.90	493.01	204.28	472.24	339.07	74.31
10	283.74	2486.10	1906.20	611.97	133.64	668.34	435.26	118.01
11	887.24	2923.30	2372.10	700.26	404.85	912.75	619.47	120.33
12	470.39	3198.50	2626.70	721.83	240.42	1316.70	1059.10	247.97
13	420.95	3335.50	2649.60	782.38	207.12	1777.50	1426.30	401.22
14	356.80	3182.70	2455.20	843.27	166.52	2075.90	1558.30	570.01
15	250.46	2984.70	2200.60	833.14	156.37	2232.30	1559.80	678.96
16	265.11	2690.80	1825.20	810.10	170.18	2166.10	1400.20	723.81
17	116.82	2288.90	1600.60	643.06	66.65	1920.80	1295.90	591.89
18	248.31	1620.80	1153.70	397.48	177.49	1392.60	937.88	378.66
19	190.19	1013.40	680.45	269.33	78.42	788.11	513.49	218.55
20	48.73	510.84	340.70	122.75	24.42	311.47	210.56	76.17
21	24.55	126.32	77.02	25.48	17.52	105.22	60.45	22.85
22	9.90	14.26	11.62	1.32	8.59	13.87	10.43	1.53
23	8.71	9.50	9.24	0.22	6.56	8.59	7.47	0.53
24	8.71	9.50	9.16	0.18	6.15	8.18	7.29	0.52

* No data available.

Lake Diefenbaker, June, 87
System Temperatures

By Day

	DCP temperature (deg C)				Solar Panel Temperature (deg C)				Ambient Air Temperature (deg C)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	*	*	*	*	*	*	*	*	*	*	*	*
2	14.47	18.12	16.70	1.39	8.01	16.01	11.98	2.10	7.21	16.21	11.55	3.36
3	10.03	24.84	17.12	5.30	8.01	25.01	16.76	6.12	7.21	27.62	17.29	7.35
4	11.96	34.42	22.81	7.99	8.01	31.82	18.36	7.58	5.81	34.42	19.87	9.61
5	15.04	31.17	22.77	5.73	12.01	31.82	22.02	7.00	11.21	34.62	21.91	7.71
6	16.69	32.37	25.11	4.44	14.01	31.22	22.68	5.50	12.01	34.42	22.91	7.07
7	15.78	28.95	22.17	4.16	10.21	23.81	17.59	5.04	9.21	28.22	18.31	7.04
8	*	*	*	*	*	*	*	*	*	*	*	*
9	15.95	27.47	23.67	4.13	15.81	30.42	24.87	3.78	15.01	32.82	24.77	4.55
10	18.80	29.01	22.54	3.49	16.81	30.42	21.81	4.65	15.61	32.02	21.32	5.45
11	16.17	34.59	24.38	6.51	13.41	30.42	22.01	6.25	12.21	34.02	22.27	7.94
12	16.46	31.29	24.96	4.52	13.61	32.22	24.26	6.81	12.41	34.82	24.06	7.87
13	28.49	33.68	31.08	2.59	16.01	17.21	16.61	0.60	14.41	15.41	15.01	0.53
14	19.54	38.58	28.16	6.45	13.61	37.22	25.39	7.66	12.21	38.22	24.89	8.77
15	22.39	37.35	30.42	5.44	20.21	36.62	30.70	5.76	18.81	41.02	30.56	7.57
16	22.42	39.44	30.78	5.54	18.61	38.02	26.01	6.24	17.21	40.22	25.70	7.65
17	14.43	32.43	25.58	4.36	14.41	27.62	21.24	4.49	13.41	32.42	21.47	6.13
18	26.06	44.00	29.76	8.71	11.41	39.42	26.18	8.71	10.41	39.42	25.65	10.05
19	21.82	31.63	26.78	3.18	15.01	32.22	21.87	4.90	14.41	33.42	21.21	5.90
20	18.12	26.10	21.83	2.63	15.61	28.02	20.06	2.90	14.01	29.62	19.34	5.04
21	16.81	31.06	22.74	5.14	15.01	31.02	24.08	6.18	13.61	34.02	23.94	7.55
22	19.03	27.75	22.35	2.90	15.41	26.02	20.56	3.52	13.61	30.42	20.16	4.75
23	15.95	22.91	19.52	2.14	11.81	25.31	17.39	4.03	10.21	27.82	16.86	5.29
24	13.79	20.91	17.05	2.30	10.21	19.61	15.56	3.28	9.01	20.81	15.26	4.16
25	11.79	28.27	19.35	5.93	8.41	24.81	16.91	5.70	7.41	29.62	17.79	7.68
26	15.84	38.13	26.17	7.74	11.61	33.02	23.62	7.51	10.21	37.22	23.64	9.31
27	20.06	33.85	26.34	4.43	15.61	30.42	22.33	5.05	15.01	34.02	22.56	6.76
28	17.06	23.02	19.94	1.78	14.01	23.01	18.81	2.59	13.01	25.41	18.46	3.59
29	14.93	34.46	23.80	7.47	13.61	30.22	20.81	6.19	12.61	33.22	20.92	7.74
30	16.98	23.76	18.83	1.85	13.81	20.81	16.24	2.20	12.41	19.61	15.15	2.39

By Hour of Day

	DCP temperature (deg C)				Solar Panel Temperature (deg C)				Ambient Air Temperature (deg C)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	13.39	30.66	22.32	4.30	8.01	21.21	15.43	3.63	7.21	20.01	14.04	3.49
2	12.36	28.36	20.99	4.03	8.61	19.41	14.83	3.16	7.81	18.61	13.55	3.17
3	11.51	26.84	19.81	3.82	8.61	19.81	14.21	3.31	7.41	18.01	13.06	3.14
4	10.94	25.64	19.17	3.69	8.81	20.21	14.13	3.55	8.61	19.21	13.01	3.45
5	10.42	24.56	18.32	3.56	8.01	20.21	13.97	3.29	5.81	18.81	12.80	3.13
6	10.05	23.70	17.60	3.46	10.81	23.01	16.01	3.10	10.01	22.01	15.25	3.00
7	10.14	23.42	17.30	3.28	11.41	24.61	18.68	3.58	11.01	23.21	16.45	2.99
8	10.82	23.42	17.58	3.17	14.01	27.82	20.41	3.87	14.21	28.62	20.62	3.61
9	12.92	24.56	18.50	3.15	15.21	35.92	22.16	4.39	15.41	33.92	22.45	4.18
10	13.96	25.98	19.80	3.15	17.41	34.62	23.77	4.53	16.41	34.82	24.17	4.21
11	15.55	28.36	21.37	3.36	18.81	37.02	25.52	4.41	19.41	37.62	26.80	4.54
12	16.69	30.66	22.83	3.59	18.41	37.42	26.51	4.63	16.81	38.62	28.55	4.99
13	17.46	32.37	24.46	4.05	17.01	38.42	27.34	5.13	16.21	39.42	29.75	5.75
14	17.83	34.14	25.77	4.43	14.61	38.62	28.07	5.73	14.61	41.02	30.68	6.76
15	18.18	36.04	26.91	4.87	15.01	38.62	27.11	6.54	14.41	40.42	29.17	7.54
16	18.18	38.41	27.73	5.15	15.21	38.22	27.04	6.60	14.01	40.02	28.45	7.53
17	19.09	39.44	28.95	5.32	14.61	37.82	27.18	5.20	13.41	37.62	28.28	5.72
18	19.20	39.38	29.79	5.83	16.61	39.42	26.78	5.23	15.01	37.62	26.71	4.93
19	17.15	42.29	29.86	6.37	16.01	33.42	24.51	5.90	15.01	31.82	23.74	4.94
20	16.12	44.00	29.89	6.14	14.41	34.02	22.65	5.03	14.21	33.42	21.80	5.01
21	17.89	43.54	29.25	6.01	13.01	30.22	19.50	3.99	12.21	28.42	18.24	3.92
22	16.92	40.58	27.87	5.92	11.41	27.62	17.66	4.01	10.81	26.21	16.32	3.94
23	15.67	36.81	25.97	5.33	9.01	23.21	16.50	3.67	8.61	22.41	15.03	3.57
24	14.47	33.45	24.14	4.83	8.01	23.21	15.92	3.82	7.21	22.21	14.56	3.72

* No data available.

Lake Diefenbaker, June, 87
System Voltages

by Day

	Battery (volts)				PV Panel (volts)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	*	*	*	*	*	*	*	*
2	12.65	13.07	12.79	0.1e	0.04	13.30	5.71	e.7e
3	12.54	14.07	13.02	0.51	0.03	14.19	9.45	6.05
4	12.62	14.21	13.09	0.53	0.04	14.62	9.53	e.1e
5	12.61	14.30	12.99	0.4e	0.05	14.63	9.41	6.09
e	12.59	14.25	13.04	0.52	0.0e	14.64	9.37	e.14
7	12.60	14.31	13.04	0.54	0.05	14.74	9.55	e.05
8	*	*	*	*	*	*	*	*
9	12.61	13.82	13.06	0.44	0.07	14.51	11.20	5.08
10	12.5e	13.71	12.92	0.39	0.06	13.99	10.44	5.41
11	12.57	14.22	13.02	0.54	0.06	14.60	9.94	5.80
12	12.60	13.92	13.0e	0.45	0.06	14.42	10.78	5.39
13	12.64	12.6e	12.65	0.01	0.09	0.12	0.11	0.02
14	12.57	13.93	12.94	0.43	0.07	14.20	9.54	5.91
15	12.60	14.01	13.00	0.43	0.10	14.38	11.07	4.78
1e	12.59	13.61	12.86	0.33	0.08	13.8e	8.52	6.19
17	12.59	13.98	12.97	0.45	0.07	14.34	9.54	5.93
18	12.59	14.11	12.99	0.48	0.06	14.54	9.61	5.94
19	12.60	13.60	12.87	0.31	0.0e	13.83	9.33	5.87
20	12.5e	13.63	12.88	0.34	0.05	14.00	9.34	5.91
21	12.55	13.94	13.02	0.49	0.05	14.34	10.70	5.39
22	12.58	13.82	12.95	0.3e	0.0e	13.9e	11.07	4.e8
23	12.55	14.27	12.93	0.45	0.05	14.12	9.44	5.92
24	12.52	13.60	12.90	0.37	0.04	13.92	9.52	5.88
25	12.51	14.22	12.99	0.5e	0.04	14.64	9.59	5.98
2e	12.5e	14.00	12.9e	0.48	0.05	14.44	9.48	5.97
27	12.58	13.54	12.8e	0.33	0.0e	13.93	9.22	5.90
28	12.55	13.40	12.79	0.27	0.04	13.85	9.05	5.92
29	12.52	13.88	12.95	0.42	0.04	14.05	9.30	6.04
30	12.61	12.98	12.72	0.12	0.05	13.32	9.48	5.76

by Hour of Day

	Battery (volts)				PV Panel (volts)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
1	12.53	12.67	12.62	0.03	0.04	0.09	0.0e	0.02
2	12.53	12.6e	12.61	0.03	0.04	0.09	0.06	0.01
3	12.53	12.64	12.59	0.03	0.03	0.08	0.06	0.01
4	12.51	12.63	12.58	0.03	0.08	0.32	0.18	0.07
5	12.52	12.62	12.58	0.03	4.49	9.93	8.07	1.49
e	12.54	12.64	12.59	0.03	12.42	12.92	12.82	0.12
7	12.55	12.6e	12.61	0.03	12.83	12.94	12.88	0.03
8	12.57	12.80	12.68	0.0e	12.88	13.04	12.9e	0.04
9	12.62	12.94	12.78	0.10	12.92	13.19	13.04	0.08
10	12.59	13.2e	12.91	0.16	12.88	13.42	13.13	0.14
11	12.93	13.54	13.29	0.16	13.07	13.77	13.44	0.16
12	12.8e	13.80	13.52	0.21	13.25	14.0e	13.79	0.19
13	12.78	14.06	13.61	0.28	13.07	14.23	13.94	0.2e
14	12.71	14.31	13.81	0.42	13.05	14.62	14.07	0.37
15	12.67	14.2e	13.69	0.44	12.99	14.74	14.13	0.47
1e	12.69	13.67	13.3e	0.2e	12.97	14.32	13.84	0.3e
17	12.70	13.4e	13.28	0.18	13.01	13.95	13.69	0.22
18	12.8e	13.32	13.13	0.13	13.07	13.73	13.52	0.1e
19	12.67	13.08	12.94	0.11	12.6e	13.4e	13.2e	0.17
20	12.65	12.91	12.81	0.07	12.12	13.30	13.1e	0.2e
21	12.63	12.77	12.71	0.03	9.52	13.03	12.41	0.88
22	12.59	12.72	12.67	0.03	1.12	5.30	3.09	1.13
23	12.56	12.71	12.6e	0.03	0.05	0.16	0.09	0.03
24	12.55	12.69	12.65	0.03	0.04	0.11	0.07	0.02

* No data available.

Lake Diefenbaker, June, 87
System Currents

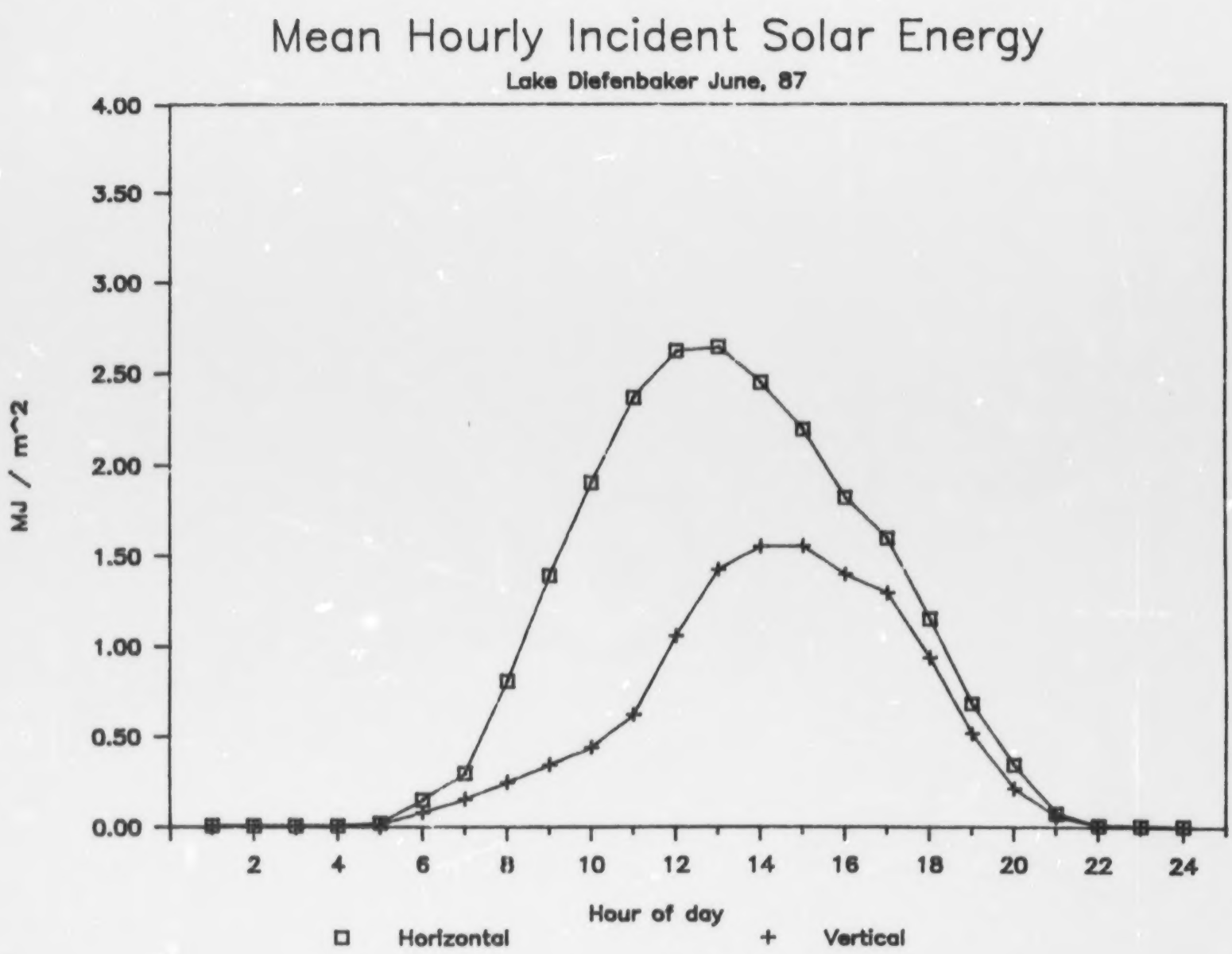
by Da.

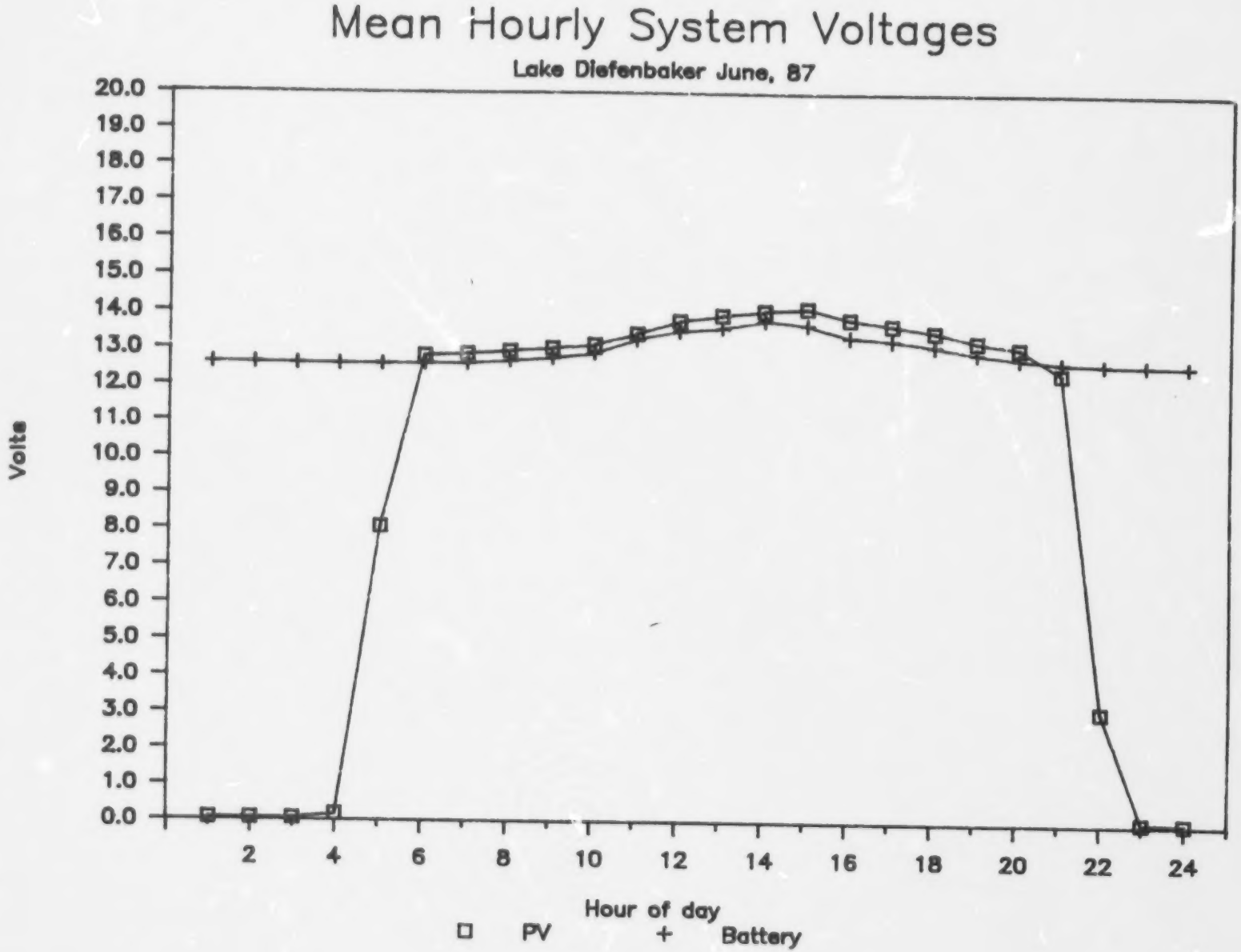
	Charge (mA)				Discharge (mA)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
	*	*	*	*	*	*	*	*
	-0.2e	30.94	8.51	13.14	2e.14	45.31	3[illegible].7e	7.01
	-0.32	305.6e	86.51	111.0e	28.91	45.99	[illegible]	7.44
4	-0.32	410.60	107.33	136.60	29.14	47.3e	35.61	7.5e
	-0.3e	404.e0	91.49	127.22	29.37	4e.90	35.77	7.55
	-0.38	415.17	105.e9	137.22	29.82	47.13	36.07	7.56
	-0.38	410.95	101.71	137.94	29.37	46.67	35.78	7.5e
	*	*	*	*	*	*	*	*
	-0.32	355.9e	110.51	120.82	29.82	4e.90	35.44	7.42
	-0.2e	333.33	7e.89	93.87	29.82	4e.e7	35.74	7.51
	-0.44	391.e8	102.5e	133.40	29.37	47.58	35.56	7.44
	-0.32	327.85	107.45	114.91	29.82	4e.90	36.08	7.4e
	-0.11	2.15	1.02	1.60	30.51	30.51	30.51	0.00
14	-0.50	399.56	97.98	132.68	29.82	48.27	36.39	7.71
15	-0.50	353.01	92.84	113.38	30.28	48.04	35.73	7.[illegible]
1e	-0.44	299.8e	5e.2e	90.85	30.28	48.04	35.91	7.63
17	-0.38	406.80	97.52	133.60	30.05	47.13	36.16	7.58
18	-0.51	402.30	99.55	134.20	29.82	48.95	3e.54	7.71
19	-0.38	283.16	e9.30	85.60	29.82	47.13	3e.15	7.6[illegible]
2[illegible]	-0.2e	328.45	63.84	88.09	29.e0	4e.e7	35.62	7.[illegible]
21	-0.20	405.82	111.69	137.22	29.37	46.90	35.93	7.55
22	-0.2e	275.00	74.4e	75.35	29.82	4e.22	35.20	7.31
23	-0.2e	309.24	67.95	92.03	29.37	4e.22	35.39	7.53
24	-0.20	187.24	62.94	66.51	29.14	45.7e	35.14	7.5e
25	-0.38	410.84	99.36	137.43	29.14	4e.e7	35.51	7.52
2e	-0.44	400.e8	98.93	132.15	29.37	48.04	3e.15	7.64
27	-0.32	355.57	77.72	107.43	29.82	47.3e	3e.1e	7.ee
28	-0.20	257.9e	52.91	74.75	29.37	4e.22	35.33	7.59
29	-0.44	3e5.39	97.37	117.77	29.14	47.58	35.91	7.65
3[illegible]	-0.2e	87.52	2e.99	28.19	29.60	45.99	35.8e	7.90

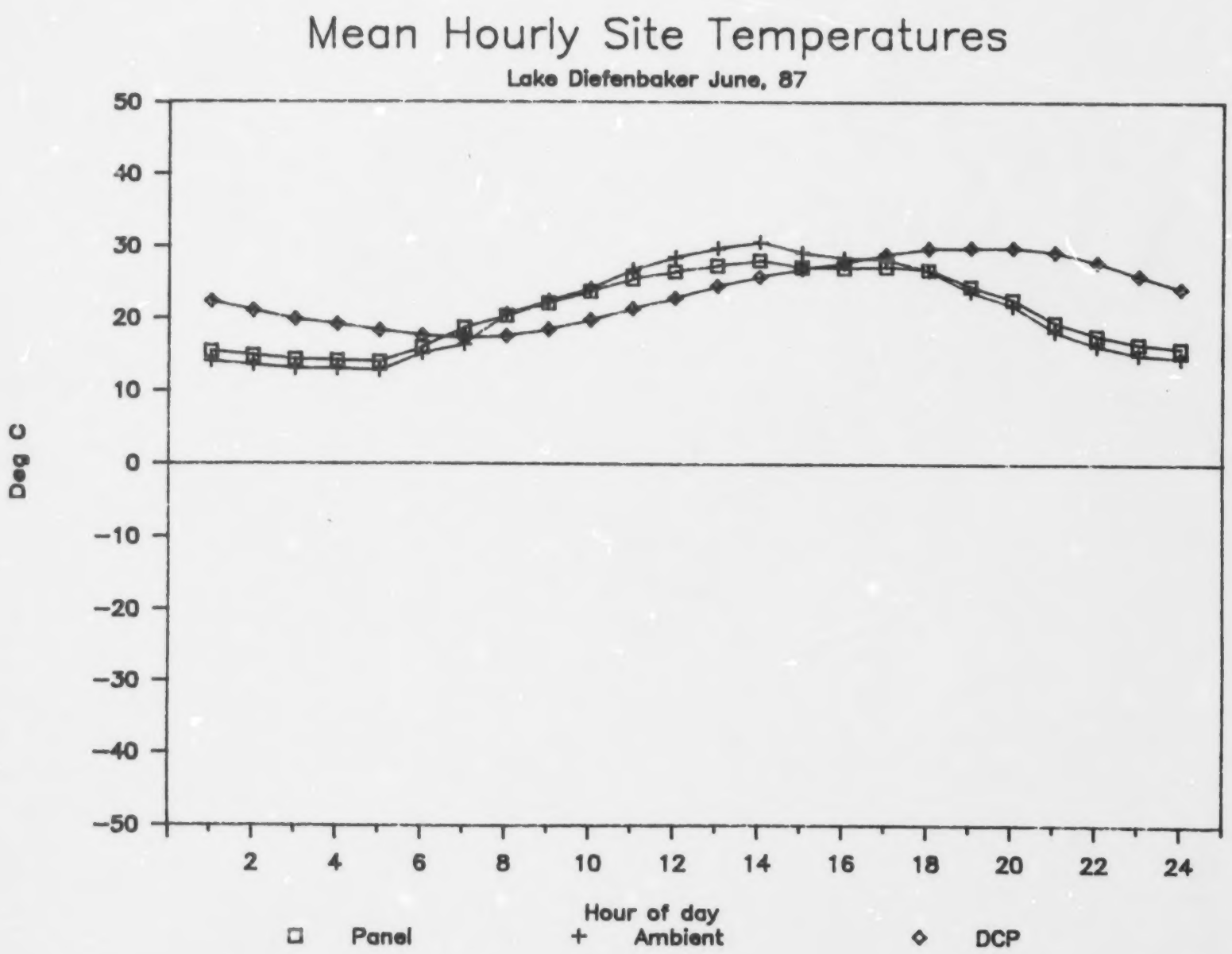
by Hour of Day

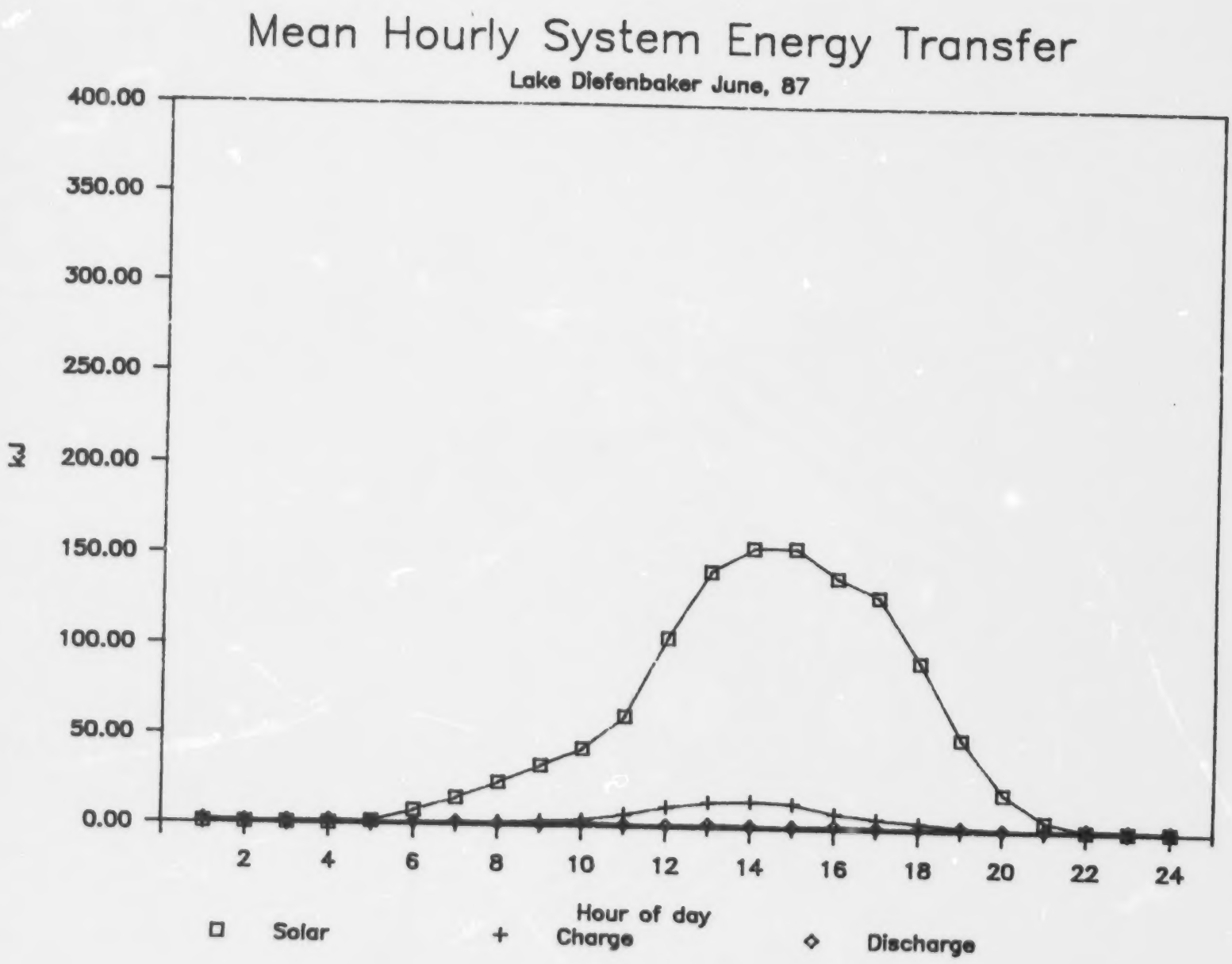
	Charge (mA)				Discharge (mA)			
	Min	Max	Avg	Std Dev	Min	Max	Avg	Std Dev
	-0.38	-0.0e	-0.23	0.07	44.62	47.13	45.88	0.57
	-0.05	0.19	0.0e	0.07	2e.91	30.2e	29.e7	0.35
	2.15	2.39	2.26	0.07	2e.91	30.28	29.5e	0.34
4	-0.32	-0.02	-0.18	0.07	44.62	4e.45	45.54	0.48
	0.07	1.51	0.74	0.47	29.14	30.28	29.71	0.32
	5.39	20.e8	13.75	3.28	29.37	30.28	29.88	0.29
	16.71	37.48	25.45	5.31	44.85	46.67	45.84	0.44
	27.25	65.11	42.84	10.85	29.37	30.51	30.04	0.29
	28.45	92.64	63.33	15.45	29.60	30.96	30.22	0.33
	21.73	135.71	84.13	24.41	45.7e	4e.90	4e.24	0.33
	74.28	197.76	149.61	30.26	30.05	31.65	30.8e	0.41
12	44.63	291.10	240.5e	61.84	30.28	32.33	31.31	0.47
13	35.93	37e.0e	297.39	89.77	45.54	47.36	46.57	0.53
14	28.52	410.95	307.24	115.65	30.05	32.78	31.82	0.72
15	28.64	415.17	287.08	126.52	30.05	32.78	31.85	0.77
1e	28.19	277.43	185.99	80.81	45.54	48.04	46.65	0.63
17	8.90	171.34	130.27	42.09	30.05	32.5e	31.58	0.64
18	32.5e	125.99	94.29	24.17	30.28	32.33	31.47	0.60
19	8.16	73.31	53.37	16.17	45.54	48.50	46.93	0.78
20	0.29	47.78	28.78	11.54	2e.82	32.56	31.10	0.57
21	2.15	15.82	8.52	3.76	29.82	32.56	30.84	0.60
22	-0.51	-0.20	-0.36	0.09	45.31	48.95	46.72	0.88
23	-0.17	0.13	-0.03	0.08	29.37	30.96	30.10	0.44
24	2.03	2.33	2.18	0.07	29.14	30.73	29.99	0.43

* No data available.

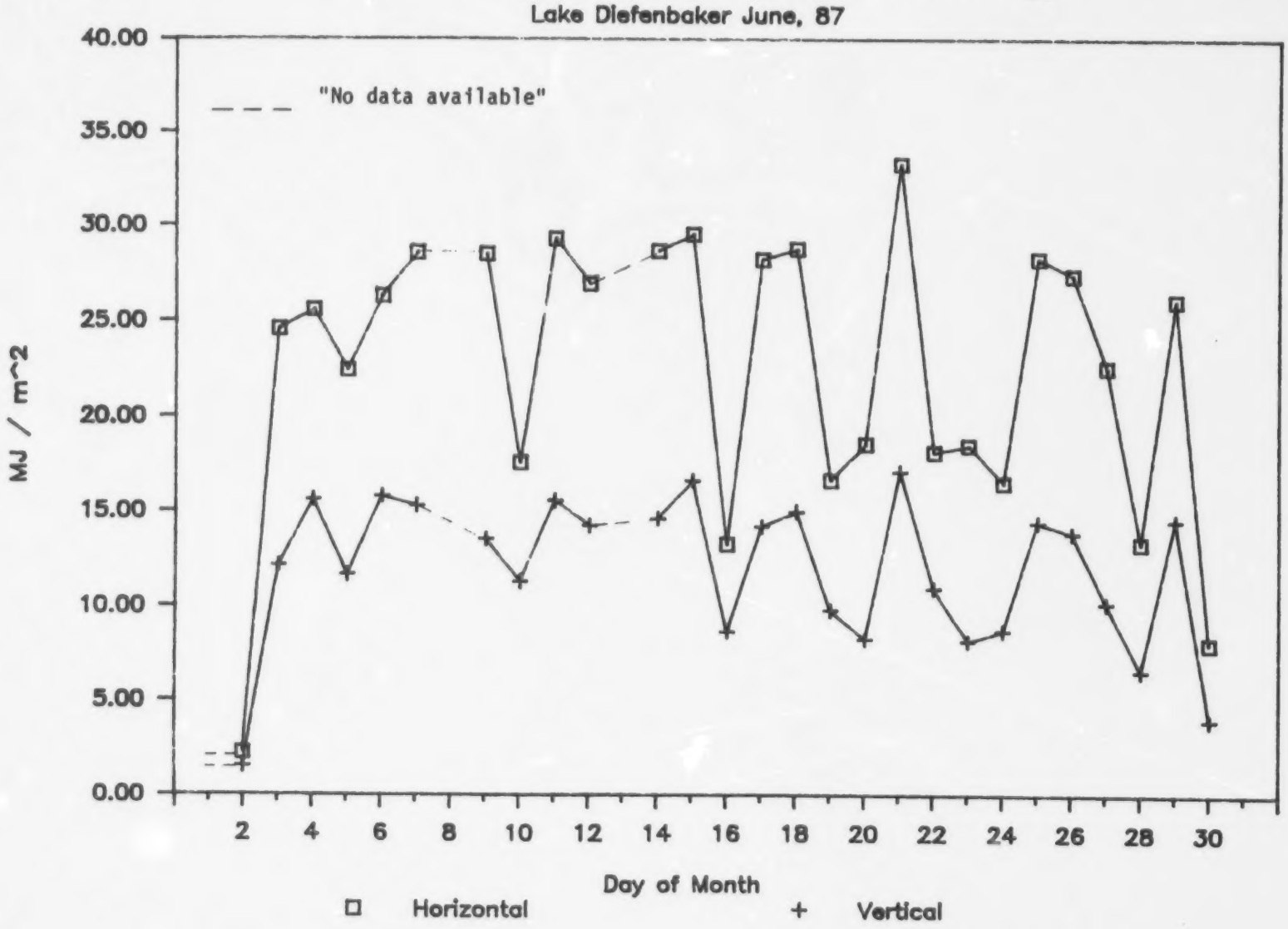

Mean Hourly Incident Solar Energy
Lake Diefenbaker June, 87
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
MJ / m^2
2
4
6
8
10
12
14
16
18
20
22
24
Hour of day
Horizontal
Vertical


Mean Hourly System Voltages
Lake Diefenbaker June, 87
Volts
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2
4
6
8
10
12
14
16
18
20
22
24
Hour of day
PV
Battery


Mean Hourly Site Temperatures
Lake Diefenbaker June, 87
50
40
30
20
10
0
-10
-20
-30
-40
-50
Deg C
2
4
6
8
10
12
14
16
18
20
22
24
Hour of day
Panel
Ambient
DCP

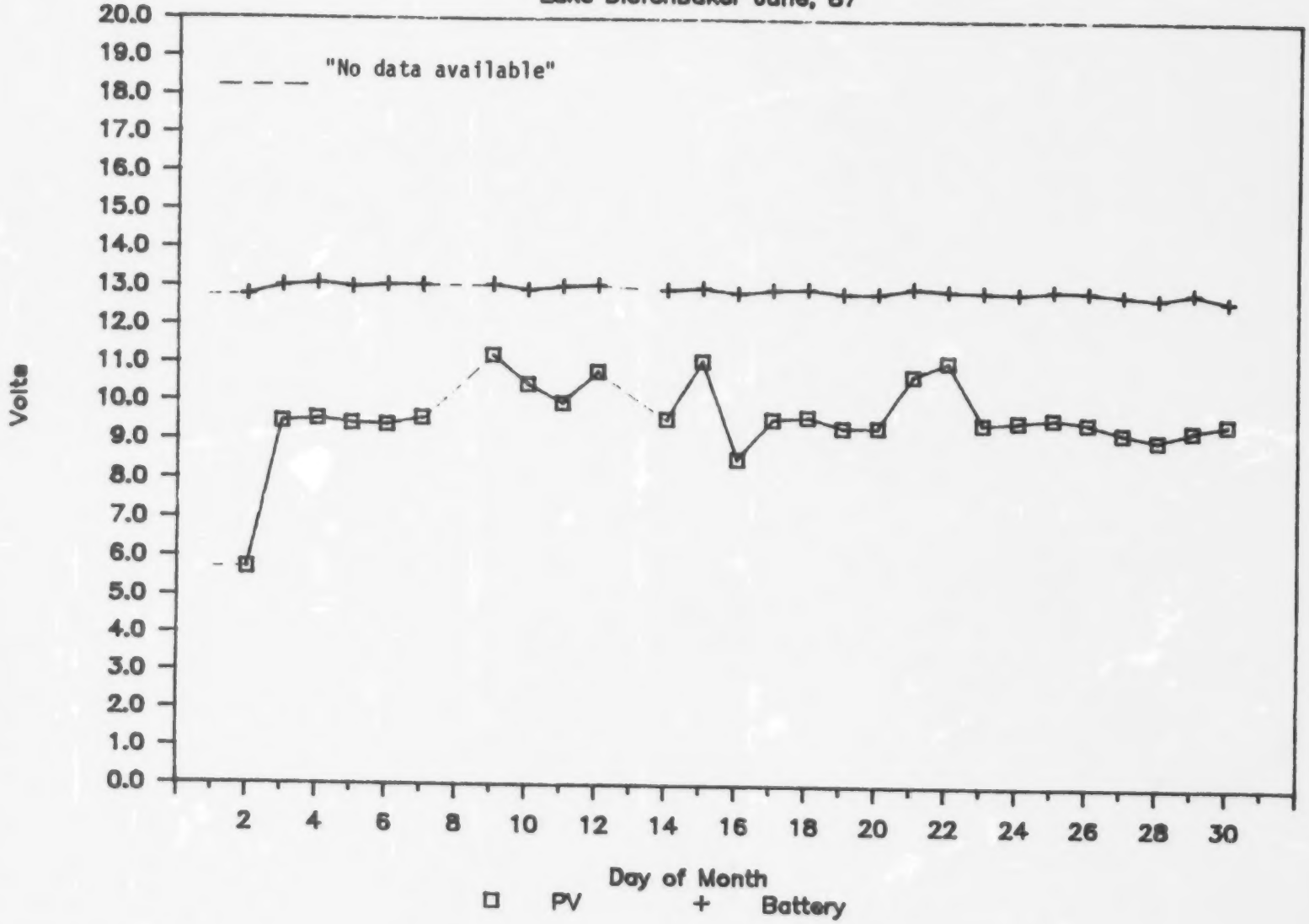

Mean Hourly System Energy Transfer
Lake Diefenbaker June, 87
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
kJ
2
4
6
8
10
12
14
16
18
20
22
24
Hour of day
Solar
Charge
Discharge

Total Daily Incident Solar Energy



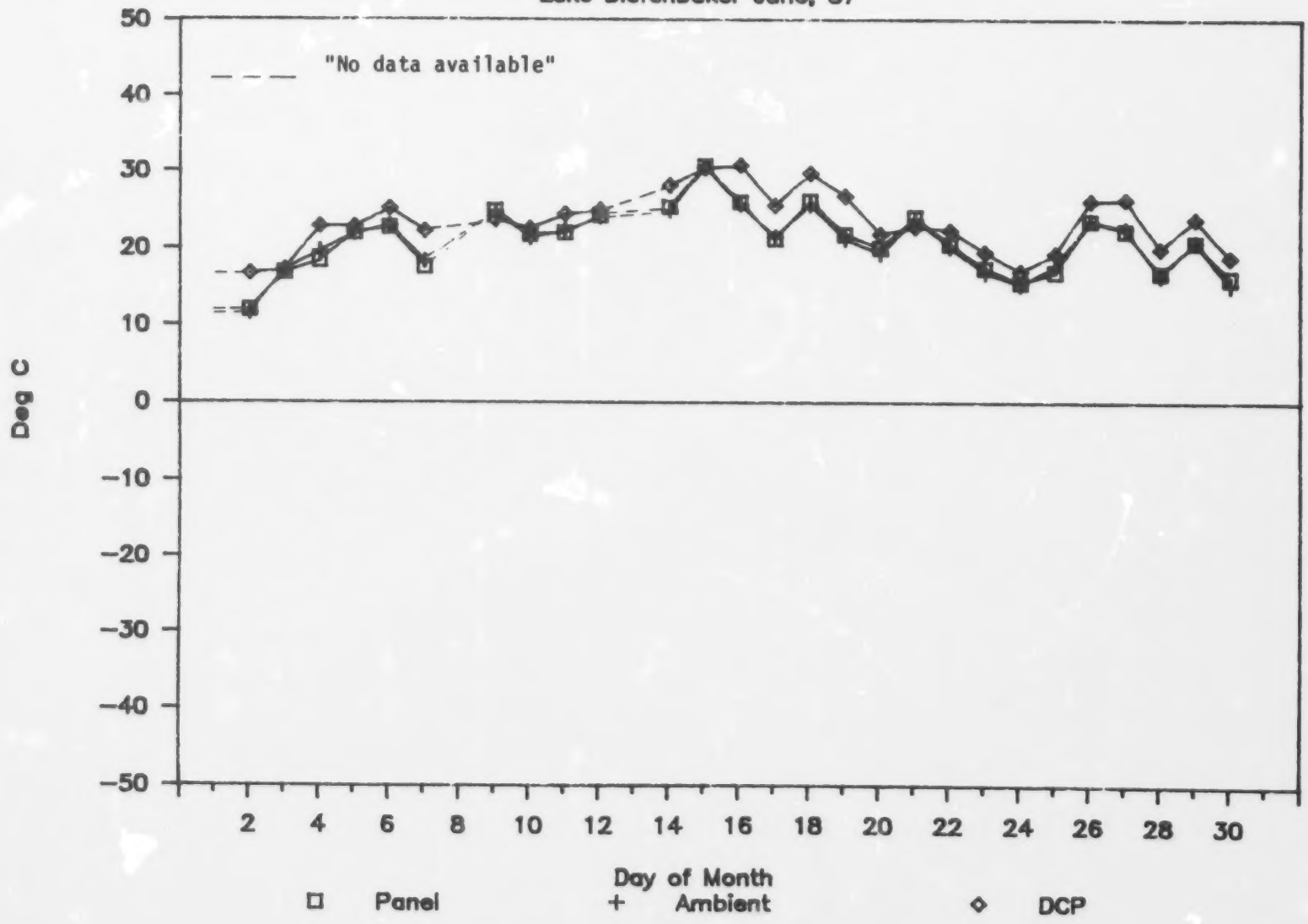
Mean Daily System Voltages

Lake Diefenbaker June, 87



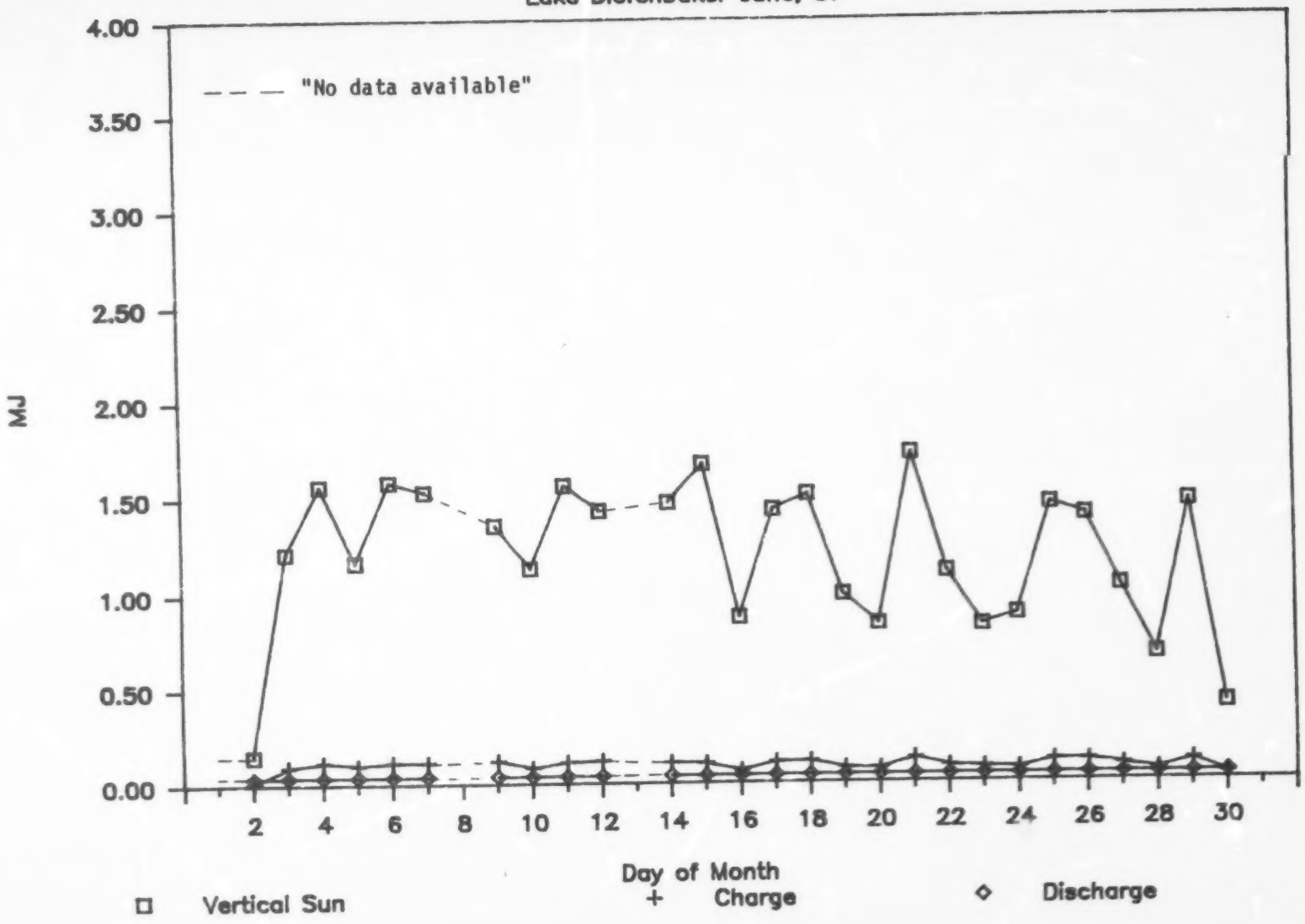
Mean Daily Site Temperatures

Lake Diefenbaker June, 87



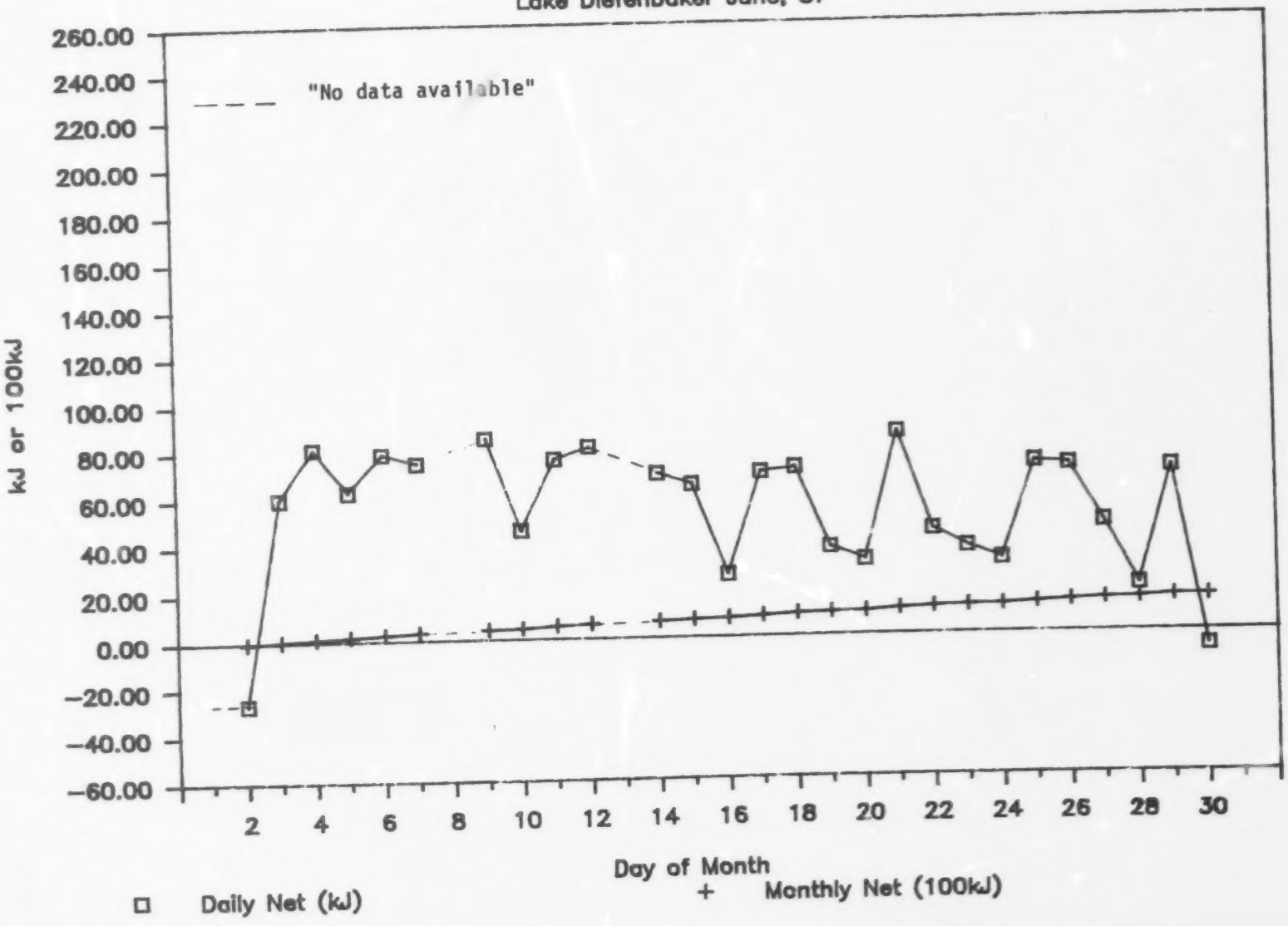
Total Daily System Energy Transfer

Lake Diefenbaker June, 87



Battery Charge Level

Lake Diefenbaker June, 87



After the release of the draft copy of this report, some of the missing data were retrieved from Environment Canada, Water Resources Branch, Hull. This appendix is added as an update to the report.

The following set of graphs and tables were generated using additional data retrieved from Environment Canada, Water Resources Branch, Hull. This additional data is part of the "missing" data mentioned in the body of the report. Due to archiving of the 1986 data files only 1987 data were readily available from Environment Canada. The following table shows the number of monitoring hours. Please note that due to the method of storing data in the datalogger, the number of usable monitoring hours is less than the number of retrieval monitoring hours. The table shows that an additional 32% of data were retrieved for Coppermine River and an additional 33% of the data were retrieved from Lake Diefenbaker. This increases the monitoring hours to 67% of calendar hours for Coppermine River and 69% for Lake Diefenbaker.

To demonstrate the effects of the additional data, only the horizontal and vertical solar insolation graphs were regenerated. Graphs 1 to 4 correspond to graphs 1 to 4 of Appendix A while graphs 6 to 9 correspond to graphs 1 to 4 of Appendix B. Graphs 5 and 10 correspond to graph 11 of Appendix A and B respectively. As can be seen from comparison of the line graphs, the major effect of the additional data has been to smooth out the plots. The shape and peak values for the Coppermine River contours have remained the same although the peak values for the Lake Diefenbaker plots have dropped. This drop is due to the additional hours of data occurring on overcast days.

In conclusion the increase in retrieved data has increased the statistical validity of the generated engineering unit data.

Coppermine River

	Calendar Hours	Previously Retrieved Hours	Previously Usable Hours	With Additional Data Retrieved Hours	With Additional Data Usable Hours
Jan	744	372	346	600	579
Feb	672	354	353	543	539
Mar	744	408	396	507	498
Apr	720	184	156	220	191
May	744	453	436	543	532
Jun	720	537	524	588	576
TOTAL	4344	2308	2211	3001	2915

Lake Diefenbaker

	Calendar Hours	Previously Retrieved Hours	Previously Usable Hours	With Additional Data Retrieved Hours	With Additional Data Usable Hours
Feb*	672	69	68	69	68
Mar	744	445	432	639	629
Apr	720	509	503	636	630
May	744	279	266	530	520
Jun	720	602	594	636	630
TOTAL	3600	1904	1863	2510	2477

*Lake Diefenbaker started transmitting data on February 25, 1987.

Site: Coppermine River, N.W.T.

PV Panel - Manufacturer: Solarex
Model: AH0816000
Type: SX10

Battery - Manufacturer: VARTA
Model: P-125
Type:

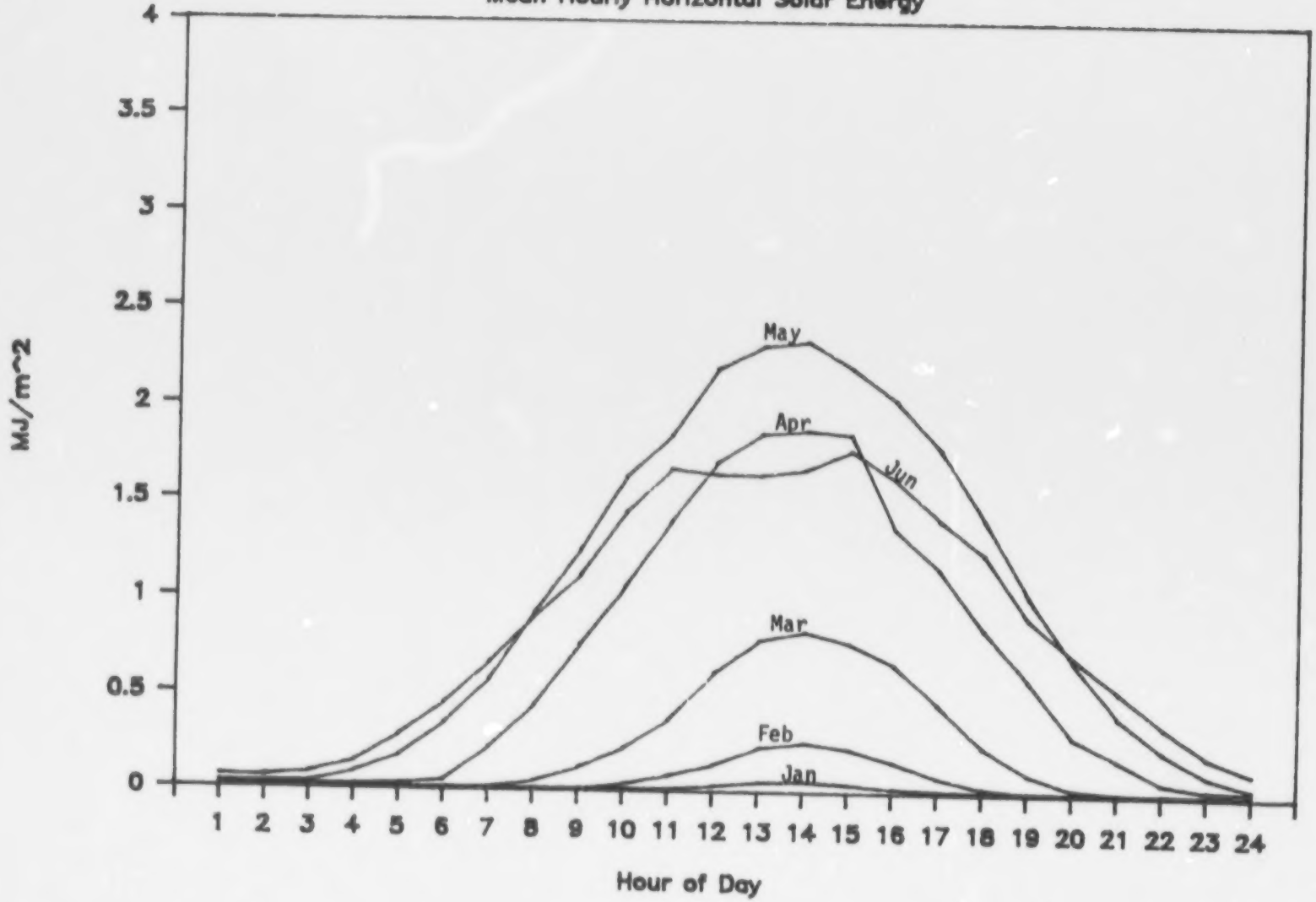
Operated by: Environment Canada, Water Resources Branch

Month/Year	Total Avail. Hours	Actual Hours	Mean Daily Horizontal Solar Energy (MJ/m^2)	Mean Daily Vertical Solar Energy (MJ/m^2)
Nov/86	720	653	0.50	1.27
Dec/86	744	363	0.03	0.09
Jan/87	744	579	0.45	0.60
Feb/87	672	539	1.35	4.35
Mar/87	744	498	5.42	13.04
Apr/87	720	191	15.96	20.51
May/87	744	532	23.79	25.23
Jun/87	720	576	20.82	15.70
Jul/87	744			
Aug/87	744			
Sep/87	720			
Oct/87	744			
Nov/87	720			
Dec/87	744			

Graph 1

Coppermine River

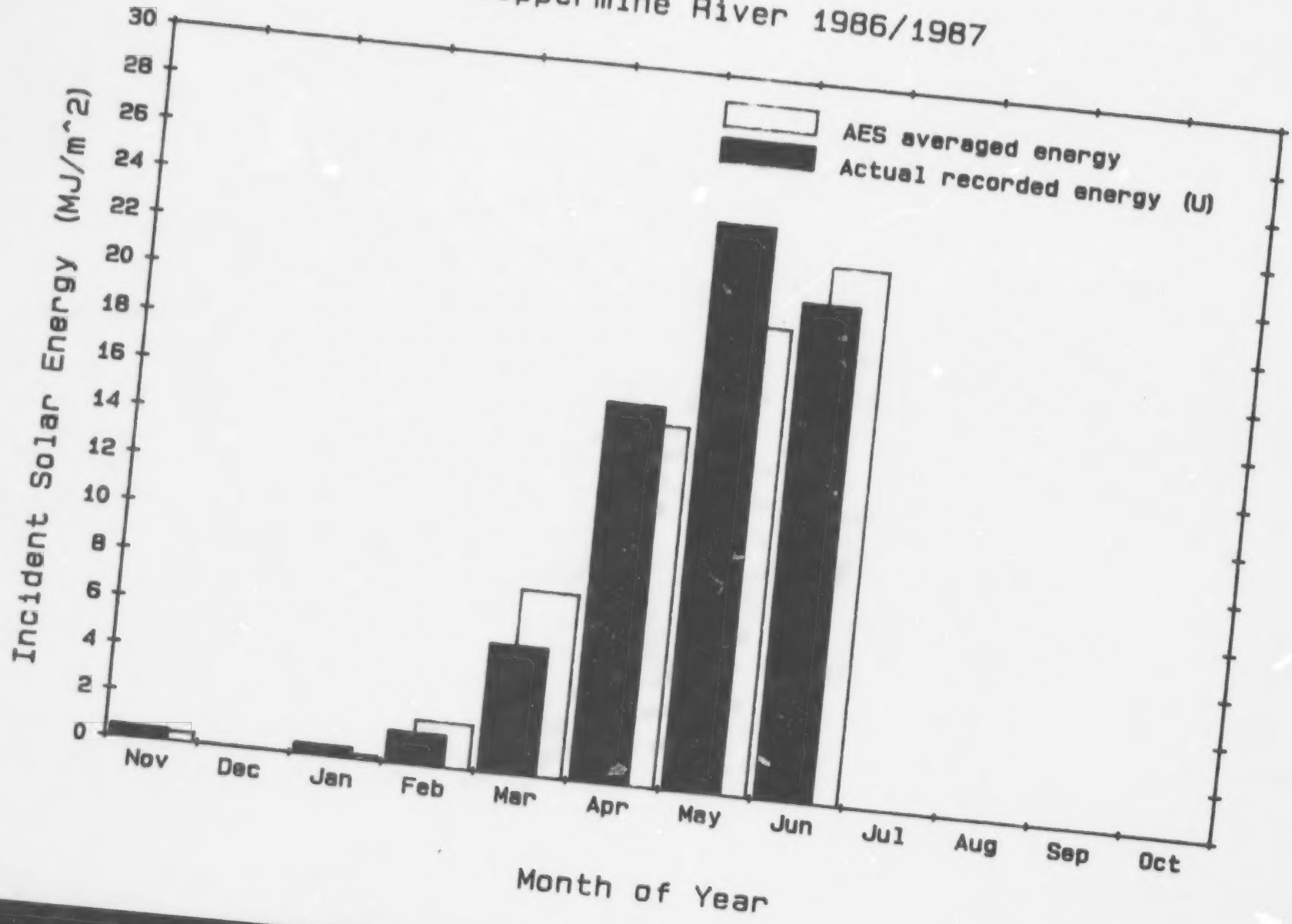
Mean Hourly Horizontal Solar Energy



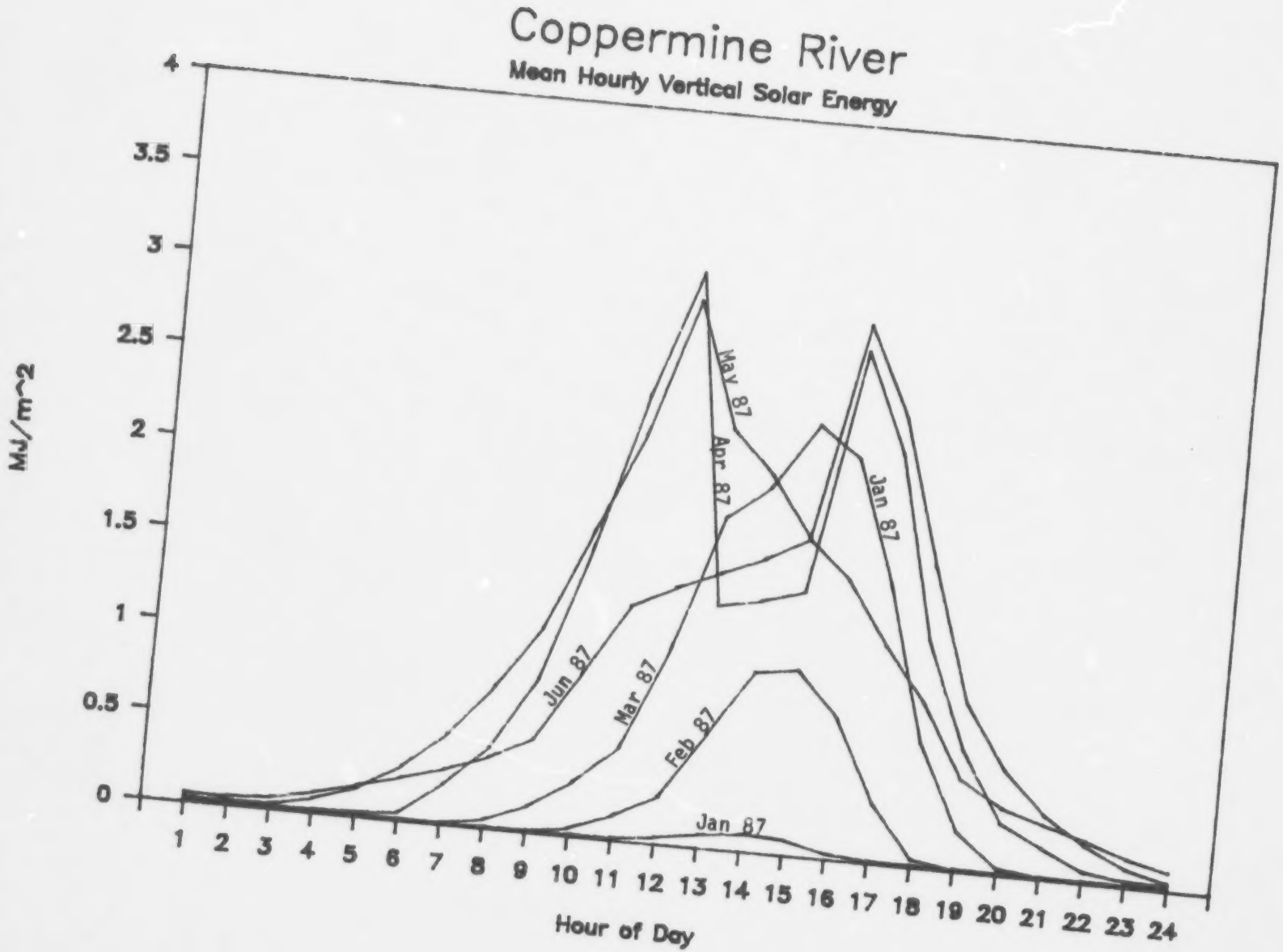
Graph 2

Mean Daily Horizontal Solar Energy

Coppermine River 1986/1987



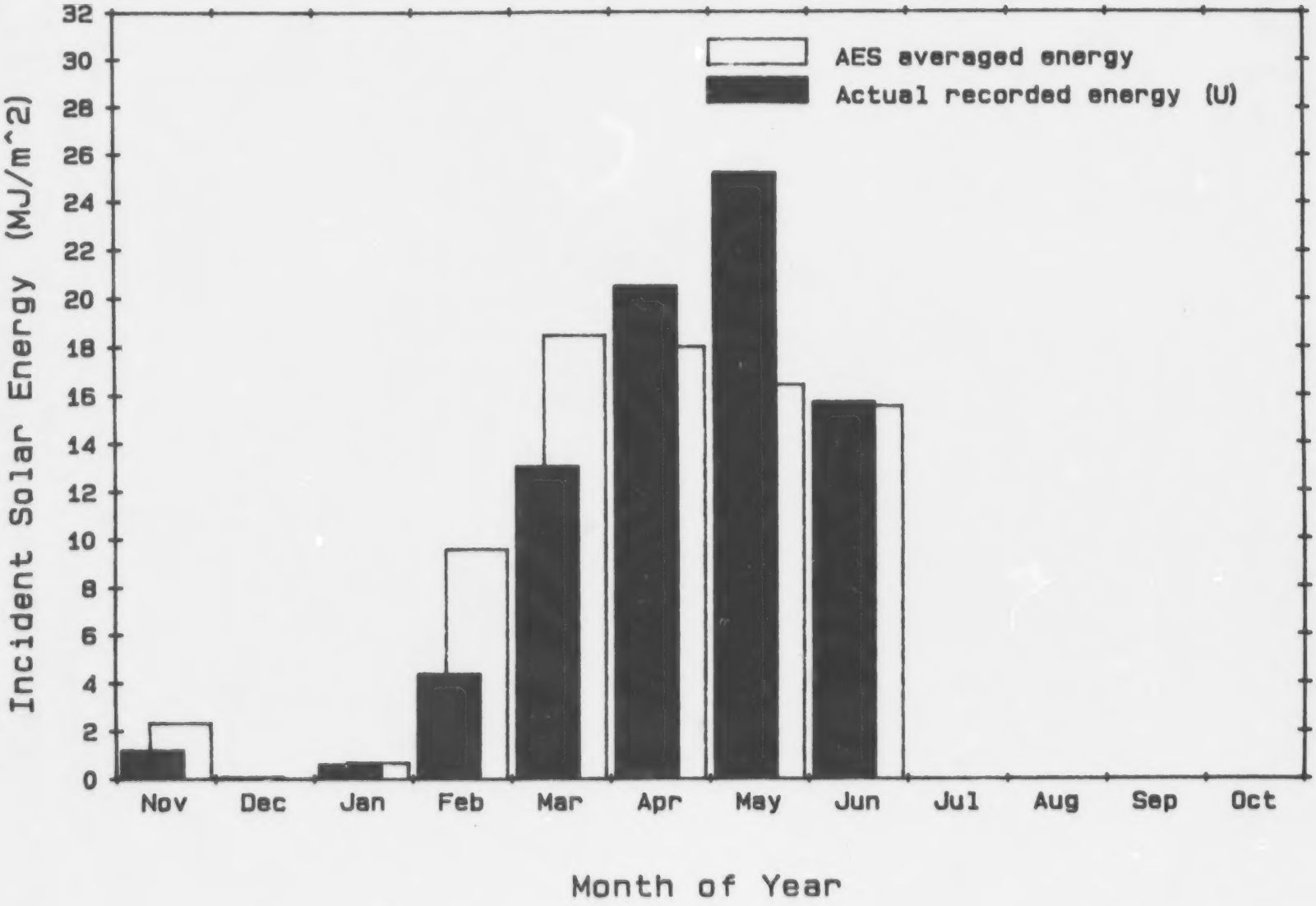
Graph 3


Coppermine River
Mean Hourly Vertical Solar Energy
MJ/m^2
4
3.5
3
2.5
2
1.5
1
0.5
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day
May 87
Apr 87
Jan 87
Jun 87
Mar 87
Feb 87
Jan 87

Graph 4

Mean Daily Vertical Solar Energy

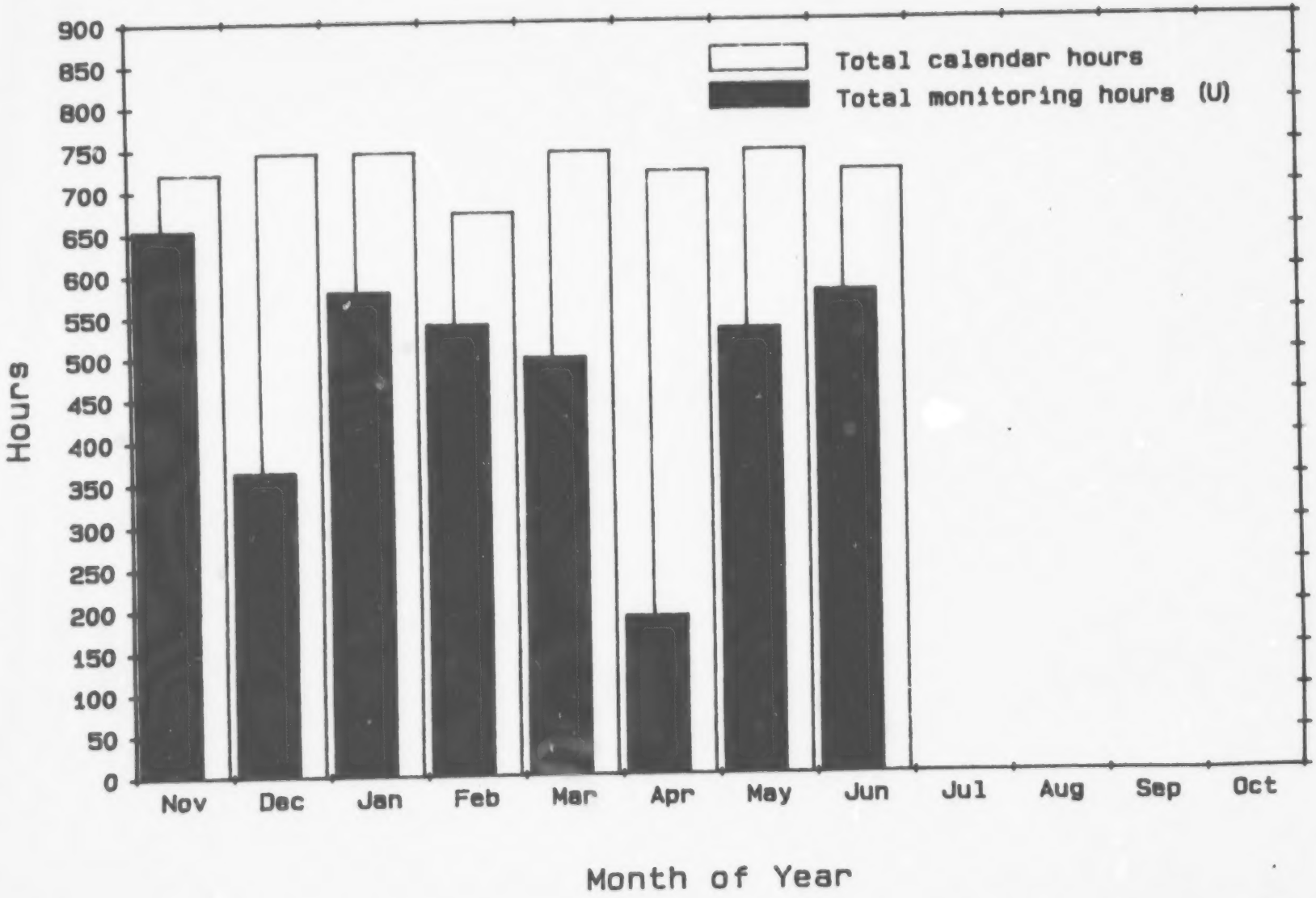
Coppermine River 1986/1987



Graph 5

Calendar Hours vs. Monitoring Hours

Coppermine River 1986/1987



Site: Lake Diefenbaker, Saskatchewan

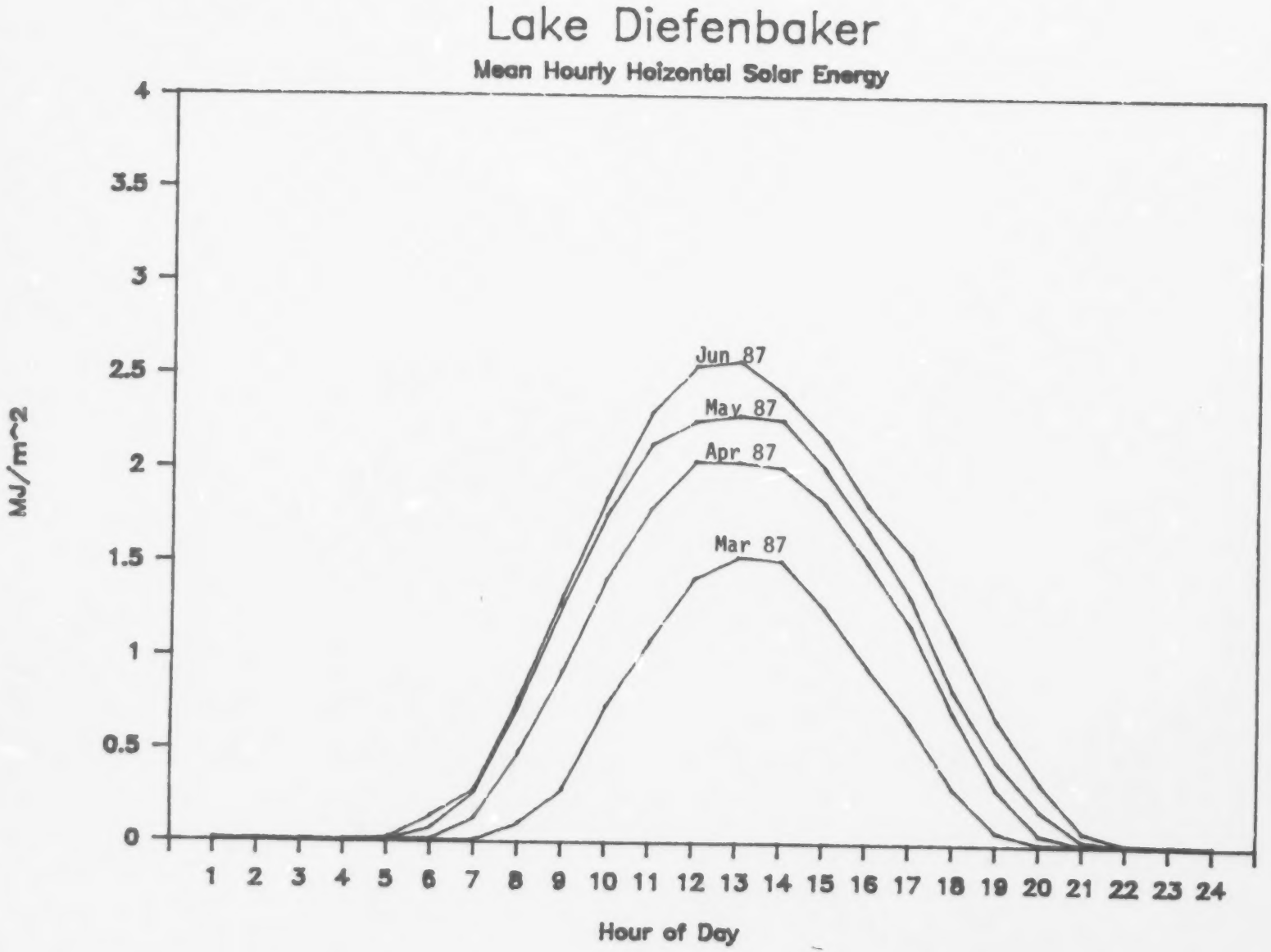
PV Panel - Manufacturer: Solarex
Model: AH0811000
Type: SX10

Battery - Manufacturer: VARTA
Model: P-125
Type:

Operated by: Environment Canada, Water Resources Branch

Month/Year	Total Avail. Hours	Actual Hours	Mean Daily Horizontal Solar Energy (MJ/m^2)	Mean Daily Vertical Solar Energy (MJ/m^2)
Nov/86	720	-	-	-
Dec/86	744	-	-	-
Jan/87	744	-	-	-
Feb/87	672	69	11.89	27.98
Mar/87	744	629	10.07	12.03
Apr/87	720	630	16.55	14.16
May/87	744	520	19.68	12.30
Jun/87	720	630	22.10	11.74
Jul/87	744			
Aug/87	744			
Sep/87	720			
Oct/87	744			
Nov/87	720			
Dec/87	744			

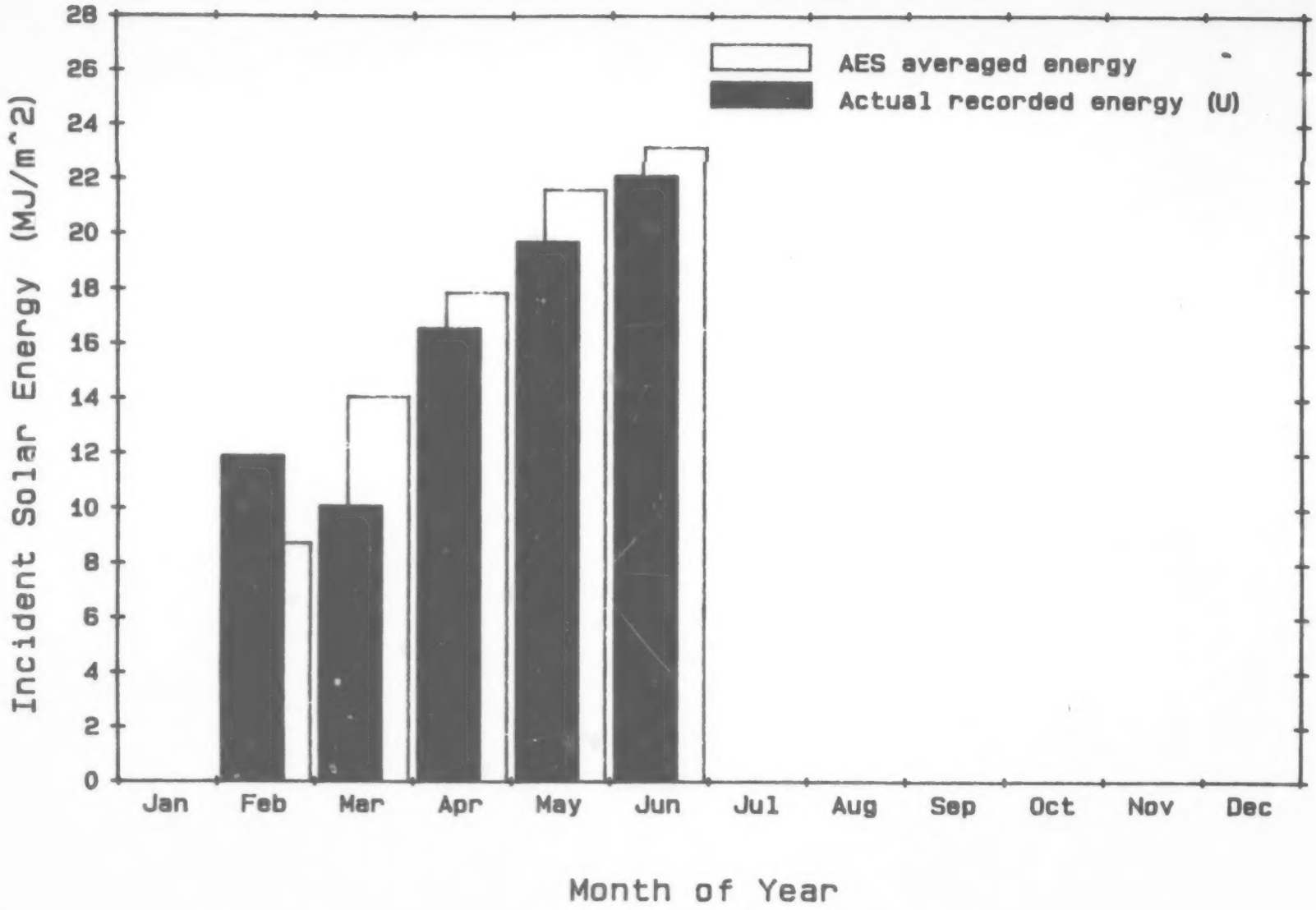
Graph 6


Lake Diefenbaker
Mean Hourly Hoizontal Solar Energy
MJ/m^2
4
3.5
3
2.5
2
1.5
1
0.5
0
Jun 87
May 87
Apr 87
Mar 87
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day

Graph 7

Mean Daily Horizontal Solar Energy

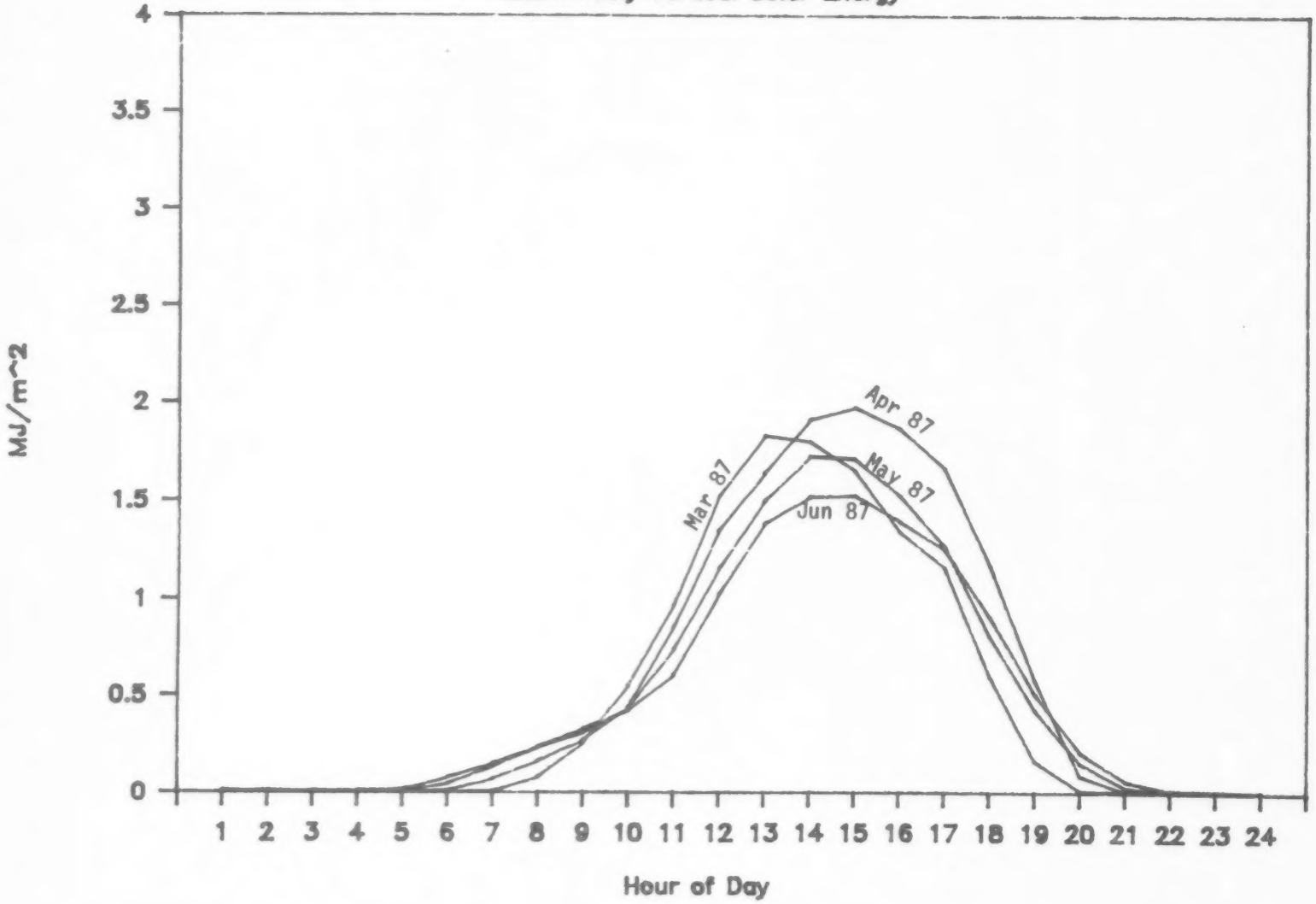
Lake Diefenbaker, 1987



Graph 8

Lake Diefenbaker

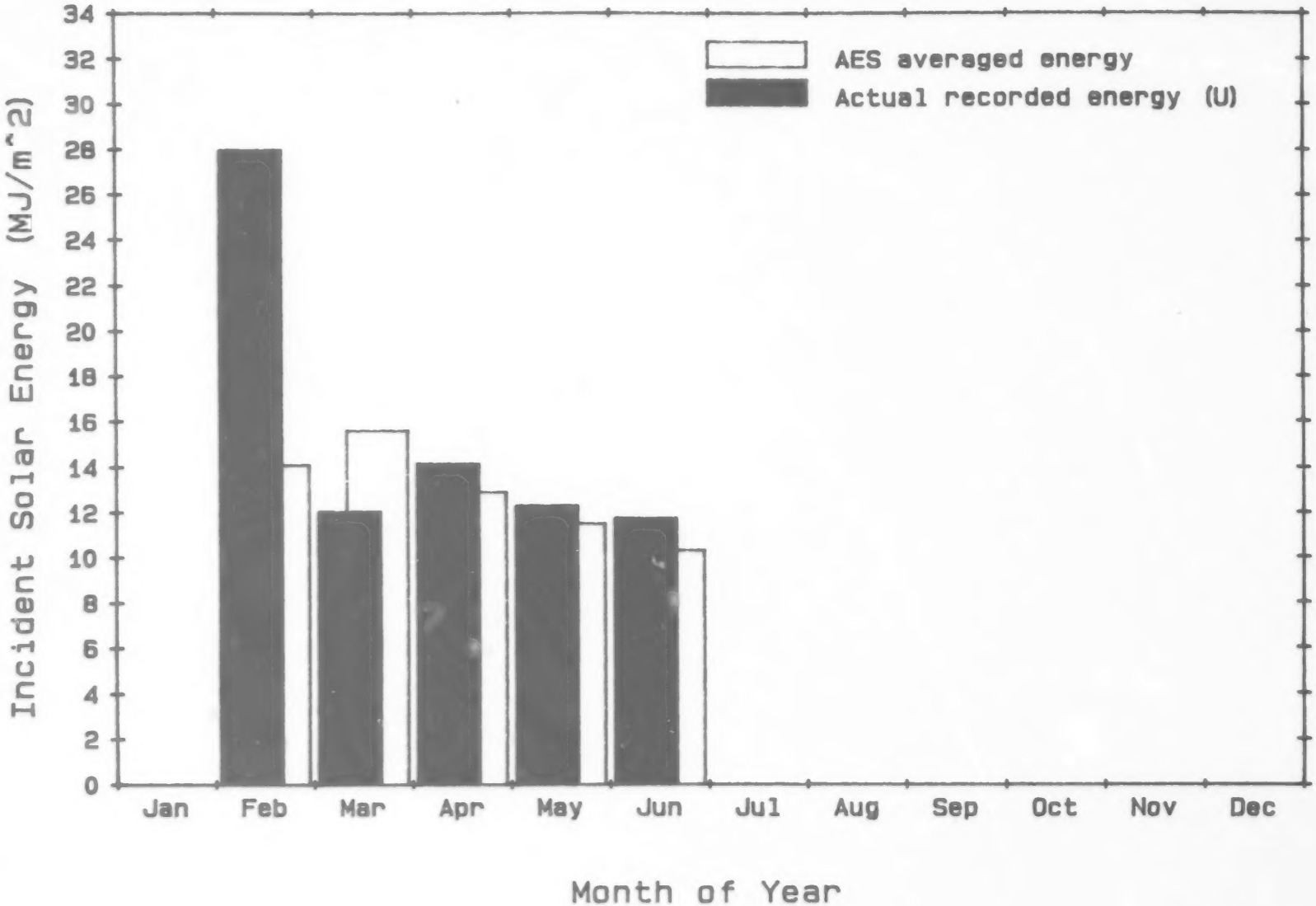
Mean Houly Vertical Solar Energy



Graph 9

Mean Daily Vertical Solar Energy

Lake Diefenbaker, 1987



Graph 10

Calendar Hours vs. Monitoring Hours

Lake Diefenbaker 198?